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JOURNAL
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VOL. 27 OCTOBER, 1934 No. 5

Nineteenth Annual Meeting of the Pacific Slope Branch American Association of Economic Entomologists

The 19th annual meeting of the Pacific Slope Branch was held at the University of California, Berkeley, California, June 19–22, 1934. The meetings were called to order at 10:30 a. m., June 19th by Chairman C. I. Reeves. Papers were presented during the forenoon and afternoon of the 19th, 20th and 21st. Friday morning, June 22, was given over to a joint meeting with the Pacific Coast Entomological Society, the Lorquin Entomological Club and the Entomological Society of America.

Saturday morning was given over to a visit to the California Academy of Sciences in Golden Gate Park followed by lunch in San Francisco.

The annual entomologists dinner was held on the evening of June 21st with Vice-chairman Herms in charge.

The total attendance at the Berkeley meetings numbered 121, among which were the following members:

H. M. Armitage
E. D. Ball
A. D. Borden
H. E. Burke
Lewis A. Burtch
Roy E. Campbell
L. W. Campbell
Earl W. Cannon
Rodney Cecil
L. R. Cody
W. C. Cook
Heber C. Donohoe
J. E. Eckert
E. O. Essig
J. R. Eyer
Stanley B. Freeborn
Stanley E. Flanders
W. B. Herms
W. H. Hoskins
Philip C. Johnson
Meredith L. Jones
G. F. Knowlton
J. F. Lamiman
M. D. Leonard
Harold C. Lewis
A. C. Mason
A. E. Michelbacher
William Moore
William B. Parker
H. J. Quayle
George I. Reeves
C. F. Rosling
Fred P. Roullard
H. A. Scullen
Henry H. Severin
George D. Shafer
Leslie M. Smith
C. J. Sorenson
John B. Steinweden
Lloyd L. Stitt
A. F. Swain
H. A. Tibbetts
Frank E. Todd
E. P. Van Duzee
George H. Vansell
Robert K. Vickery
R. L. Webster
G. R. Wilson
R. S. Woglum
Chas. C. Woodworth
F. H. Wymore
G. F. York

PART I. BUSINESS MEETING

The following committees were appointed: Nominating committee: R. L. Webster, Chas. J. Sorenson, H. E. Burk. Auditing committee: J. R. Eyer, H. J. Quayle, Loyd L. Stitt. Representatives to the meeting of the Affiliated and Associated Societies: W. B. Herms, H. A. Scullen.

The auditing committee reported favorably on the following financial statement of the treasurer:

Balance on hand June 14, 1933		$ 7.41
Interest		.11
Refund from parent society for 1933 meetings		21.02
Cash paid out:		
Expenses connected with special letter to members	$ 9.75	
Postage (meeting notices, manuscripts)	10.14	
Telegrams	1.07	
Addressing envelopes	4.00	
Mimeographing programs	11.06	
	$36.02	$28.54
Overdraft		7.48
	$36.02	$36.02

The committee's report was accepted.

The nominating committee submitted the following nominations:

Chairman: H. E. BURKE
Vice-Chairman: WILLIAM MOORE
Secretary-Treasurer: H. A. SCULLEN

The committee's report was accepted and the officers nominated were elected.

A communication was read by the secretary from Dr. E. F. Phillips, president of the National Association.

It was moved and carried that a vote of thanks be extended to the local men who have helped to make the meetings a success.

It was announced that future meetings will be held as follows: 1935 at U. C. L. A., Los Angeles; 1936 at Seattle.

PART II. PAPERS

THE POSITION OF NICOTINE IN CODLING MOTH CONTROL[1]

By R. L. WEBSTER and JAMES MARSHALL, *Washington Experiment Station*

Investigations on organic insecticides for codling moth control, conducted by the Washington Experiment Station, were initiated at Wenatchee in 1927, when Anthony Spuler undertook a study of nicotine sulphate on orchard plots. It was in 1926, as many of you will remember, that the first objections were raised to arsenic residue on apples, and the following season many non-arsenical insecticides, as well as numerous non-lead arsenicals, were studied anew in connection with codling moth control.

USE OF NICOTINE SULPHATE ALONE.—At that time the so-called standard concentration of lead arsenate in the Pacific Northwest was two pounds per 100 gallons. In 1927 Spuler substituted nicotine sulphate for lead arsenate in the second and third cover sprays on blocks of Spitzenburg and Arkansas Black trees. This was used at the rate of 1–600 (one and one-half pints to 100 gallons) and one pound of cresol soap was added to each 100 gallons of spray material.

Five cover sprays were applied, three of which were of lead arsenate alone, two of nicotine sulphate 1–600. Even though the experimental orchard had been very wormy the year before, the percentage of wormy fruit was low both in the Spitzenburg and Arkansas Black trees where nicotine sulphate and soap were used and in the corresponding lead arsenate checks.

Spitzenburg apples generally are susceptible to codling moth injury, while Arkansas Blacks are resistant. The final counts showed that 4.7 per cent of the Spitzenburg apples and 1.4 per cent of the Arkansas Black apples were wormy. Thinnings and drops, as well as harvested fruits, were included in computing these figures. The use of lead arsenate 2–100 on the check blocks reduced the percentage of worms to 1.5 on the Spitzenburg block and to .9 per cent on the Arkansas Black trees. While the amount of wormy fruit on the trees where nicotine sulphate was used in the two cover sprays was not high, still on the Spitzenburg block there was three times the percentage of wormy fruit as compared to the lead arsenate check.

Feeling that nicotine sulphate was deserving of further trial, Spuler

[1]Published as Scientific Paper No. 291, College of Agriculture and Experiment Station, State College of Washington.

included orchard plots on Romes in his investigations during 1928 (1). Nicotine sulphate was used alone at the rate of one pint per 100 gallons (1–800) and also with mineral oil, in which case the quantity of nicotine sulphate was cut down to one-half pint (1–1600). Where nicotine sulphate was applied at the rate of 1–800 for five cover sprays in 1928 the percentage of wormy fruit was 6.6, which was compared with Romes sprayed with lead arsenate 2–100, on which there was 3.9 per cent wormy fruit.

Nicotine Sulphate with Mineral Oil.—When used with one per cent mineral oil, the nicotine sulphate was cut down to one-half pint per 100 gallons (1–1600). On Romes in 1928 the oil-nicotine combination gave slightly better results than lead arsenate 2–100 when five cover sprays were applied. In this comparison there were 2.2 per cent wormy fruits on the oil-nicotine block; 3.0 per cent on the lead arsenate check.

Investigations in 1929.—In 1929 Spuler conducted further investigations with the oil-nicotine combination on Romes throughout the season. The materials used were in the same proportions as in 1928. Both blocks of trees had about the same degree of worm control, although the number of stings on the oil-nicotine block was far less than that on the Romes sprayed with lead arsenate 2–100 throughout the season. Comparing these two blocks, there were 27.5 worms per 1000 apples on the oil-nicotine sprayed trees, 27.1 on the lead arsenate check trees. The stings were 25 per 100 in case of the oil-nicotine block, 86 in the lead arsenate check; the difference no doubt resulting from the ovicidal value of the combination spray. Six cover sprays were applied in each case.

Differences were more marked on Jonathans in 1929, where the oil-nicotine combination in the last two covers improved control. In this case there were 1.8 worms per 100 apples where oil-nicotine was used, 4.3 worms per 100 for a lead arsenate schedule (2–100) throughout the season.

Investigations in 1930.—Because of reduction in size of fruits where mineral oil was applied throughout the season, the use of the oil-nicotine combination was restricted to the later cover sprays in 1930. In a block of six Rome trees oil-nicotine was applied in the fifth and sixth covers, lead arsenate 3–100 being used during the first four cover sprays.

In previous comparisons lead arsenate was applied at a lesser concentration. It was about this time that growers began generally to use the larger amount of lead arsenate in their spraying operations. The oil-nicotine combination was used in the same proportions.

This oil-nicotine plot may be compared with one of six Rome trees where lead arsenate 3–100 was applied during six cover sprays. In the oil-nicotine plot there were only 1.6 worms per 100 apples; in the lead arsenate check, 2.2 worms per 100. In other words, the use of oil-nicotine in the last two covers resulted in slightly better control than when lead arsenate was used alone.

Similar results were obtained on Jonathans. One plot of six trees received an application of mineral oil and lead arsenate for the first cover spray, lead arsenate 3–100 for the second, third, and fourth cover sprays, oil-nicotine in the fifth and sixth covers. This plot may be compared to a block of Jonathans where lead arsenate 3–100 was applied. Here again the oil-nicotine plot showed a less number of worms, 2.2 per 100 apples as compared to 2.5 in the lead arsenate check.

Reduction in Size of Fruits.—While the principal objection to a nicotine-oil spray schedule throughout the season is the cost, further objection may be raised on account of possible reduction in size of fruits resulting from the continual use of mineral oil. Overley (2) pointed out that "on Romes. . . . six covers of medium or heavy oil reduce the size of fruit on trees bearing heavy crops." He goes on to say, however, that "it probably would not affect the size on trees with light crops as the leaf area per fruit would be of greater ratio."

DeSellem (3) reached a similar conclusion on the application of nicotine-oil throughout the season. Reduction in size of Jonathan and Winesap apples occurred when six applications of oil-nicotine were made in an orchard in the lower Yakima Valley in 1929.

Investigations in 1931.—For several years the use of oil-nicotine in the last two cover sprays resulted in an improvement in codling moth control, as compared to a spray schedule of lead arsenate 3–100 throughout the season. In 1931, however, the use of oil-nicotine in the last two cover sprays on a plot of six Rome trees resulted in no special improvement in control over lead arsenate 3–100; 6.2 worms per 100 apples where oil-nicotine was applied, 6.3 in case of lead arsenate 3–100.

A reason for this difference, as compared to previous years, may be found in the unusual moth activity during August and well into September, 1931. Because the oil-nicotine evidently loses its effectiveness more rapidly than lead arsenate and because of the continual onslaught of entering worms, even into September, the protection effected by the oil-nicotine was no greater in 1931 than that afforded by lead arsenate alone. The ovicidal value of the oil-nicotine was more than counterbalanced by the loss in effectiveness of that combination following the sixth cover spray, when worm activity persisted even up to harvest.

Oil-Nicotine in 1932.—The year 1932 was particularly favorable for moth activity, and orchard plots in which this combination was used were decidedly wormy, as were the near-by lead arsenate plots. This resulted in the general impression that the oil-nicotine combination had fallen down under the tremendous influx of young worms which attempted to enter the apples late in the season. Where oil-nicotine was used in the last two covers (casein-ammonia emulsion) on Romes there were 38.6 worms per 100 apples, compared to 37.8 with lead arsenate alone.

In this comparison the use of oil-nicotine in the last two cover sprays produced results practically equivalent to a straight schedule of lead arsenate (3–100) throughout the season. On the other hand, where the oil was emulsified by the tank mix method, using blood albumin, results were much less effective, 46.5 worms per 100 apples at harvest.

Mineral Oil and Nicotine Tannate.—The use of oil-nicotine tannate in late cover sprays for codling moth afforded some encouraging results. In 1931, where this combination was applied in the last two cover sprays on Romes, the test plot showed 7.7 worms per 100 apples as compared with 6.3 per 100 in the corresponding lead arsenate check, in which a concentration of 3–100 was used throughout the season.

Nicotine tannate was made by dissolving one pound of tannic acid per 100 gallons of water and adding one-half pint of 50 per cent nicotine. Standard Oil No. 6 emulsified with casein-ammonia was used at the usual rate of eight-tenths gallon per 100. On Romes in 1932 the use of mineral oil and nicotine tannate in the last two cover sprays compared favorably with lead arsenate alone, 24.9 worms per 100 apples where the oil-nicotine tannate was applied, 25.3 where lead arsenate 3–100 was used throughout the season.

Oil-Nicotine and Lead Residue.—When it became evident that serious objection from the Food and Drug Administration would be raised to lead residues on fruit, the spray application first in line as a substitute for lead arsenate for codling moth control in the Northwest was the oil-nicotine combination. Excellent results had been obtained, and it was logical to assume that this combination would result in effective control and also serve to reduce the lead load on the apples at the end of the season. In fact, the oil-nicotine combination was recommended by some agencies in 1933 primarily to reduce the lead residue, rather than for greater effectiveness in codling moth control.

Two Delicious blocks may be compared where a schedule of six cover sprays of lead arsenate 3–100 is contrasted with a spray program in which oil-nicotine was used in cover sprays 4, 5, and 6. In the second case

mineral oil and two pounds of lead arsenate were applied in the second cover, lead arsenate 3–100 in the first and third covers. The oil used was that furnished by the Standard Oil Company of California to various cooperators in the Western Oil Spray group; viscosity, 70–75 Saybolt; sulfonation test, 90.

So far as worm control is concerned, the lead arsenate-oil-nicotine combination was considered as effective. Although this block of trees was quite wormy in 1933, the combination just named resulted in 14.1 worms per 100 apples, compared with 25.9 in the check block of Delicious in which lead arsenate 3–100 was applied.

An average of five analyses of apples on these two blocks during the season indicated more than twice the quantity of arsenic present when lead arsenate was used alone; 124 micrograms of arsenic per square inch as compared to 54 micrograms. At harvest the lead load on apples in the check block was .169 grain per pound; on the oil-nicotine block, .051 grain. After washing with sodium silicate over brush machines, the lead residue was reduced to .005 grain on the check apples, .013 grain on oil-nicotine sprayed fruit.[2] In other words, there was twice as much lead residue on apples which had received lead arsenate only in the first three cover sprays, but followed with oil-nicotine in the last three cover sprays. The application of mineral oil following lead arsenate earlier in the season had made lead removal more difficult than when lead arsenate was applied throughout the season.

Summary

1. When nicotine sulphate 1–600 with soap was used in place of lead arsenate 2–100 in the second and third cover sprays in 1927 less efficient codling moth control was secured, especially in Spitzenburg apples.

2. Nicotine sulphate, one pint to 800 gallons of water, was much less efficient than lead arsenate 2–100 when both were applied throughout the season on Romes in 1928.

3. The oil-nicotine combination (one gallon summer oil, one-half pint nicotine sulphate, 100 gallons water) used throughout the season, resulted in better control than lead arsenate 2–100 on Romes in 1928.

4. Used throughout the season on Romes in 1929, the oil-nicotine combination was approximately equivalent to lead arsenate 2–100.

5. Oil-nicotine in the last two cover sprays on Jonathans in 1929 improved codling moth control over lead arsenate 2–100.

[2]Unpublished data furnished by Prof. F. L. Overley, Washington Experiment Station.

6. Oil-nicotine in the last two cover sprays on Romes in 1930 resulted in only slightly better control than when lead arsenate 3–100 was applied.

7. On Jonathans in 1930, oil-nicotine in the last two covers, oil-lead arsenate in second cover, lead arsenate 3–100 otherwise, gave results only slightly better than lead arsenate 3–100.

8. Oil-nicotine in the last two cover sprays on Romes in 1931 was practically equivalent to lead arsenate 3–100, probably due to continued worm activity late in the season.

9. The use of the oil-nicotine combination in late cover sprays in 1932 on Romes resulted in a degree of control no better than with lead arsenate 3–100 throughout the season. A heavy worm infestation in 1932 resulted in high counts of wormy fruits on all sprayed plots.

10. There was little difference in worm control on Romes in 1931, also in 1932, when the oil-nicotine tannate combination was used in place of lead arsenate in the last two cover sprays, as compared to lead arsenate 3–100 used throughout the season.

11. In a spray schedule of oil-nicotine in the last three cover applications, oil-lead arsenate in second cover, lead arsenate 3–100 in remaining cover sprays, codling moth control was greatly improved over lead arsenate 3–100 for six cover sprays on Delicious in 1933.

12. The use of mineral oil following lead arsenate made lead residue removal more difficult than when lead arsenate was used alone.

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3. DeSellem, F. E. Recent Developments in Controlling Codling Moth with Nicotine-Oil. Proc. Wash. State Hort. Assn. 25: 95–106. 1929.

FACTORS INFLUENCING PEAR THRIPS ABUNDANCE AND EFFECTIVENESS OF CULTURAL CONTROL

By STANLEY F. BAILEY, *University of California*

Ecological and extensive population studies are becoming, with limitations, a recognized necessity to the complete and successful solution of many of our entomological research problems. This is not only true of the new problems but certain of the old ones of long standing as well. Such studies have been and are being justified on the basis of forecasting the relative severity of outbreaks and the practical applications of the findings in control work.

However, it is not the purpose of this report to incite a discussion of the value of statistical analysis to the farmer but to point out some of the factors influencing the abundance of the pear thrips, *Taeniothrips inconsequens* Uzel, and some of the probable reasons for the inconsistency of cultural practices employed as control measures.

Since the pear thrips first became a pest about 30 years ago, fall plowing and irrigating have been recommended as methods of control and among the growers, proponents as well as opponents of both methods can be found. In other words, the results of these practices have been variable and the problem has continued to give concern.

The forecasting of outbreaks is most difficult since the incidence depends not only upon weather conditions but soil types, cultural practices, and local migrations. It is known that an unusual amount of rainfall either in April and May or in September and October will materially lessen the infestation the following spring but, otherwise, phenological indicators of a practical nature are not known and would doubtless be of very limited local use.

The winter is passed in the adult stage in the soil in the orchards. Weather conditions, it appears, have very little effect upon this stage. However, the emergence, which takes place during February and March (in California), seems to be directly influenced by soil temperature. Cameron and Treherne (1) stated that, in British Columbia, the "critical temperatures which determine the emergence of the adults from the soil in the spring, are 45 degrees Fahrenheit for the soil and 50 degrees Fahrenheit for the air."

At Healdsburg, California, in 1933 and 1934, the soil temperature was taken at a 6-inch depth during emergence with a Bristol recording thermometer. Significant emergence (5 adults per square yard per day) began in 1933 after three consecutive days of mean soil temperature above 54°F. and in 1934 significant emergence began after two consecu-

tive days of mean soil temperature above 54°F. The majority of thrips overwintered in the locality mentioned at an average depth of 6–7 inches and the soil was Yolo silt-loam (stream bottom phase).

While these data show nearly a 10 degree difference in the critical soil temperature initiating emergence, they cannot be compared since it is not known at what depth the above authors (Cameron and Treherne) took the soil temperature or the average depth at which the thrips were found. In this connection it should be pointed out that light, sandy, or gravelly soils usually warm up faster than heavy loam or clay soils and that the over-wintering thrips evidence vertical distribution in the soil. Thus emergence begins first on the lighter soils and the individuals nearest the surface come out first. The atmospheric temperature, the type of soil, and the extent of the vertical distribution of the adults, all directly affect the rate and period of emergence.

Early spring plowing hastens emergence and the presence of a heavy cover crop keeps the soil somewhat cooler and retards the emergence several days. In March, 1933, at Healdsburg, California, during the period of significant emergence (21 days) the daily mean soil temperature (at a 6-inch depth) beneath a heavy cover crop of vetch was 1.8°F. lower on the average than at the same depth in clean cultivated soil. While the actual difference in the soil temperatures was very small and the significant emergence retarded five days, the peak of emergence was reached the same day on both areas.

After the adults emerge from the soil, their activities of tee: egg laying, and migration are influenced by a different set of factors, chiefly food supply and atmospheric conditions. The newly-emerged adults immediately seek out suitable plant tissue on which to feed, preferably fruit buds. The stage of development and the rate of growth of the buds largely determine the amount of injury by the thrips prior to bloom. For example, if a pear and prune orchard are adjacent, and other conditions are equal, the first adults emerging in the prune orchard find the buds insufficiently open; they then migrate to the pear buds, which can be penetrated, and join those adults emerging from the pear orchard. Later emerging adults from beneath the prune trees find the prune buds swelling and showing green and there they remain. The result is severe pear bud injury and a sustaining infestation in the prune orchard. In the case of several varieties of prunes being present, the earliest blooming variety (particularly Imperial) would suffer the greater bud injury; and, if no fruit buds are available, the adults migrate to nearby ornamental and native hosts, such as willow, bay, maple, etc.

It is to be understood that the coincidence of the thrips emergence and

the stage of development of the fruit buds varies from year to year, subject to weather conditions, and while one variety may evidence severe injury one season, the following year it may escape serious damage. In addition, the amount of bud injury is to be associated with the length of time between the "green-bud" stage and full bloom and the peak of emergence. Thus, if full bloom is delayed and the peak of emergence has been reached or nearly so, severe injury results. Such a condition often leads to a shortage of food and available tissue for egg-deposition and the adults migrate to other orchards in the locality, producing unforeseen infestations.

The majority of the eggs are inserted in the flower parts and stems and in the latter case, if present in large numbers, the stems are weakened and the flowers or small fruits fall to the ground. In this manner, the larval infestation is reduced since many eggs fail to hatch. Heavy rains also cause many larvae to fall from the trees before they are mature.

After completing their development on the trees, the full-grown larvae drop to the ground, crawl down through the dry surface mulch and continue downward until they encounter an obstruction or find a suitable niche in the moist soil at which point they form a crude earthen cell. The depth to which the larvae go depends on the type and condition of the soil. They find it easy to make their way to the greatest depth in the open, porous type of soil. If a plow sole is present, the majority of the larvae find it difficult to enter this tightly packed layer. At the time the larvae are moving downward, and previous to the time the cells are constructed, any mechanical disturbance of the soil crushes and kills many of these delicate forms.

As the daily mean soil temperature increases during the summer, the soil gradually becomes drier. The natural mortality resulting is dependent upon several factors: namely, the type of soil, weather conditions, the variety and age of the orchard, and the cultural practices. Observation has shown that, as a sandy soil dries out, being incapable of holding as much water as a soil with fine particles, the thrips' cells gradually crumble. The delicate, soft-bodied larvae, thus exposed, rapidly give up their body moisture and die. On the other hand, a loam or clay type of soil has a tendency to bake hard as it dries out and in this case, the larvae shrivel up within their cells.

The degree to which the above conditions effect the natural mortality depends upon the atmospheric temperature and the evaporating conditions. Also, the amount of leaf surface and the degree to which the ground is shaded influences the extent to which the top soil dries out. The limbs in an old prune orchard frequently touch and shade the

ground to a maximum while a young pear orchard produces a minimum of shade. Other conditions being equal, the old prune orchard supports a very large soil population and the young pear orchard practically none. It should be pointed out, however, that the prune trees, having a much greater number of blossoms and leaf surface than the pear trees, normally have a greater larval infestation.

Further, if summer irrigation is practiced, the soil moisture is kept up to the point where very few larvae become desiccated. In other words, heavy soil, which remains cool and moist during the summer months offers optimum conditions to the aestivating larvae. And, in direct contrast, any cultural practice which disturbs and aerates (i. e., dries out) the soil produces a very high mortality since desiccation is fatal to the larvae.

Fall plowing as it was employed by Moulton (2) and Foster and Jones (3) was not done until late (after the first rain) and it was purported that the control resulted from mechanical injury to the pupae. While some of the disturbed larvae may be driven deeper, the present theory of early *dry* fall plowing is that the control results from the desiccation of the *larvae*.

In partial substantiation of the above field observations, considerable data have been compiled in the laboratory, using Yolo clay soil chiefly, on the rate of mortality, etc., of the immature stages but only those figures pertinent to the immediate discussion will be used. Soil moisture appears to be relatively more important than soil temperature in relation to larval mortality. If the soil moisture falls below 9 per cent (dry weight basis), the larvae can not survive longer than three days and, regardless of the soil temperature whether it be 42°F. or 100°F., the larvae die in 24 hours or less in air dry soil (4.6 per cent moisture). Between about 10 and 13 per cent soil moisture or at about the permanent wilting percentage (12.3) the optimum condition seems to obtain. In saturated soil (29.6 per cent moisture) or at about field capacity at 77°F., the average mortality over a 24-day period was 93.2 per cent. The average mortality over a 30-day period in soil of 12.6 per cent moisture content increased with the temperature, being 14.4 per cent at 42°F. and 100 per cent at 100°F. (constant temperature in all cases).

Complete submergence in tap water at room temperature produced 100 per cent mortality of the mature larvae after 3 days exposure.

Pupation occurs in the fall, usually during October. The pupae are subject to the same soil factors as are the larvae and appear to suffer a much higher mortality than the larvae if exposed to unfavorable conditions. Foster and Jones (4) stated that the time of pupation varied con-

siderably in individual orchards, dependent upon the type of soil and whether or not early fall irrigation was practiced.

These findings were borne out by field studies which have shown that pupation begins first in the heavier soils having the highest moisture content and last (if at all) in the driest and sandiest soils. An increase in the soil moisture, by rain or irrigation, appears to stimulate pupation.

In addition to the soil moisture, the soil temperature, within certain limits, has an influence on pupation. It has been possible in the laboratory to obtain pupae 29 days after the larvae matured by keeping them in Yolo clay soil of 14 per cent moisture (which is slightly above the permanent wilting percentage) at 60°F. Adults were obtained in 50 days while the first adults were not found in the orchard (at Fairfield, California) from which the larvae were collected until 6½ months after the larvae normally entered the soil. Pupae have been obtained in the laboratory at constant temperatures ranging from 42°F. to 77°F. However, the pupae developing at 77°F. all failed to mature. From these data it would appear that the soil temperature must drop to or below about 70°F., together with optimum moisture conditions to cause the larvae to successfully transform. This condition is approached first in the heavy soils and thus pupation does not occur at the same time throughout a given locality or even in an individual orchard where the soil conditions are not uniform.

Whereas the larvae can withstand as much as 3 day's complete submergence in water, the pupae succumb within 20 hours when subjected to the same conditions. And, like the larvae, the pupae are very susceptible to drying out; in air dry Yolo clay soil (4.6 per cent moisture) at room temperature, the pupae exhibit 100 per cent mortality in less than 20 hours.

The efficiency of dry fall plowing depends upon the following factors: the time of plowing (which is regulated by the harvest), the weather following plowing, the type of plow used, the degree of vertical distribution of the thrips in the soil, the kind and age of the orchard, the presence of a plow sole, and the type of soil itself. In other words, the drier and hotter the soil gets, the better the control.

The effectiveness of fall irrigation as a control measure directed against the pupae is variable and largely dependent upon the percentage of the thrips actually in the pupal stage at the time of applying the water, the method of irrigation employed, the amount of water applied, and the water-holding capacity of the soil. It is very doubtful if the thrips are actually drowned by the addition of water to the soil and the cells also appear to be altered little by irrigation. However, the

longer a soil can be held at its field capacity, or nearly so, the greater is the mortality resulting from this unfavorable condition. This is in turn dependent upon the evaporating power of the air, the amount of moisture in the soil at the time of irrigation, and the type of soil.

From this brief discussion of the principal factors influencing the mortality of the immature stages of the pear thrips, it can be seen why variable results have been obtained from cultural practices, such as plowing and irrigating, employed as control measures. In addition, the difficulties encountered in attempting to correlate the infestation, based on injury or numbers of thrips present either on the trees or in soil, with weather conditions or some easily observed or recorded phenological event may be readily appreciated. Thus it appears to be very doubtful that specific control recommendations can be made that will be equally effective in all localities (in California) every season.

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CICADAS IN RELATION TO AGRICULTURE

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During the past several years while studying cicadas there has been brought to my attention various instances of cicada injury to cultivated plants. Injury may be produced by feeding, oviposition, and possibly by transmission of disease. It is the purpose to present in this paper some of the outstanding cases of injury by these interesting but little known insects.

As compared with many other members of the order *Homoptera*, the family Cicadidae is almost negligible as an economic pest to plants. However, certain species have caused considerable injury to crops and untold worry to many growers in various parts of the country. While the greater amount of the cicada injury is caused by the winged adults, the nymphs of some species have attracted considerable attention by checking the growth of plants by feeding on their roots.

INJURY FROM FEEDING (SAP-SUCKING).—Due to the very slow underground development of cicadas, it would seem that the nymphs could scarcely affect the growth of plants by feeding upon the roots. However, in a few instances the young cicadas have no doubt been responsible for certain injury from feeding (sap-sucking). An early record by Miss Morris (1846) states that she was firmly convinced that the nymphs of the periodical cicada, *Magicicada septendecim*, were responsible for the unhealthy condition of some fruit trees which she had under observation. Finally an examination was made of one of them, a pear tree, and she says: "Agreeably to my expectation I found the larvae of the cicada in countless numbers clinging to the roots of the tree, with their suckers piercing the bark and so deeply and firmly placed that they remained hanging for one-half hour after being removed from the earth. From a root a yard long and about an inch in diameter I gathered 23 larvae; they were of various sizes, from a quarter of an inch to an inch in length. They were on all the roots that grew deeper than 6 inches below the surface. The roots were unhealthy and bore the appearance of external injury from small punctures. On removing the outer coat of bark, this appearance increased, leaving no doubt as to the cause of the disease."

Leprieur (1877) received cicada nymphs from Teheran, Persia, where they were reported to be living on vine roots in such numbers as to destroy the plants.

The nymphs of *Carineta fasciculata* Germ. and *Fidicina pullata* Berg. are reported by Moreira (1921, 1928) as causing serious injury to coffee plants in the São Paulo state of Brazil. These are forest insects but when the land was cleared and planted to coffee and other cultivated plants, the cicadas readily became adapted to them. As many as 400 nymphs of *Fidicina* have been found on the roots of one coffee plant and often the trees die from the injury.

In his sixth annual report as Commissioner of Agriculture and Horticulture of Arizona, Morrill (1914) states that the roots of alfalfa, citrus, olive, and peach were commonly attacked by the nymphs of *Diceroprocta cinctifera* (Uhl.), (=*Tibicen*).

The nymphs of *Tibicen davisi* S. and B. were reported (Wilson, 1930) as killing out asparagus fern, *Asparagus plumosus*, plants in Palm Beach County, Florida. As many as 30 nymphs per surface cubic foot of soil were found about some of the plants. Many of the ferneries were completely ruined.

The old theory that adult cicadas live on "a diet of dew," sucked up from the dew on leaves, was quite generally accepted by biologists from before Aristotles' time to as late as 1834. In 1902, Quaintance published

the report of his observations on the feeding habits of the periodical cicada, *Magicicada septendecim*. This was the first authentic information as to how these cicadas feed on sap sucked from the tree. He found them in one orchard commonly attacking apple and peach trees and observed that where large numbers of the insects fed "the tree was quite wet along the larger limbs and trunk by the sap exuded from the punctures made." During a season of heavy emergence, this cicada must drain considerable sap from the trees.

Certain other cases have been observed where the adult cicadas have caused rather serious injury by sucking the sap from plants. In Australia, during the season of 1912, Froggatt (1913) found *Melampsalta incepta* (Walker) so abundant on peach and eucalyptus trees as to cause serious damage of which he shows two good illustrations. He says "the whole of the trunk and main branches of dozens of peaches were covered with little globules of dried gum that had exuded from the tiny puncture made by the rostrum or sucking mouth of the cicadas. Under a square inch of bark removed from a badly infested branch I counted forty-five punctures through the bark into the sap-wood beneath."

A similar attack was made on eucalyptus trees the same season. A portion of a farmer's letter to Mr. Froggatt states: "When they (the cicadas) were disturbed from the trunks of the trees, they rose like a swarm of bees. . . . . A week after they were here the gum trees all looked as if they had been wrung, as the leaves all dried up on the branches. . . . In the parts of the district where the insects appeared, scores and scores of gum trees (no others) look dry and dead."

In his bulletin, Culture of the Oriental Persimmon in California, Ryerson (1927) shows an illustration of cicada injury to the fruit and says: "In Imperial and Coachella valleys a cicada, *Tibicen cinctifera* (Uhler), (probably *Diceroprocta apache* Davis) does considerable damage (Fig. 19). This insect emerges from June to September and attacks the fruit as it nears maturity. Dates are protected from its attack by means of bags. Should the persimmon ever become commercially important in these sections, similar protection may be required."

INJURY FROM OVIPOSITION.—Cicada injury to plants, as commonly referred to in literature, is usually that produced by oviposition and it is in this activity that cicada damage to plants is most apparent and by far the most destructive. When one speaks of cicada injury we are almost immediately reminded of the great destructiveness of the well known periodical cicada, an example of which we have seen or read or heard about in many parts of the country. In this regard Marlatt (1907) refers to this cicada which after mating: "Oviposition proceeds very

rapidly and thousands of individuals may often be noted working at the same time on the same tree." The effect of oviposition in such cases often results in the weakening of the smaller twigs which may be partly broken off by the wind and in such numbers that the brown withered leaves gives the trees the appearance of having been scorched by fire. In many cases the twigs break off entirely and fall to the ground and in case they are fruit trees they may be pruned so severely of fruit bearing wood that the crop may be greatly reduced. In a letter to Marlatt (1907, p. 107–108) one grower describes the condition of the orchards in the Hudson River Valley in 1826 as follows: "They destroyed the fruitage of the orchards almost completely. Nearly all the tender branches of the trees were so wounded in the deposit of the eggs that they broke from the main stems in the following year and fell to the ground, thus completely denuding the trees of their fruit-bearing branches."

Such type of injury is especially noticeable in orchards or nursery stock grown on recently cleared ground or in the vicinity of forests or groves where the cicadas breed in great numbers.

The periodical cicada does not occur in the states west of the one hundredth meridian. However, various other species of cicadas sometimes appear in different parts of the country including the western states and since the periodical cicada is so popularly known, those who have heard about this species erroneously refer to it as the 17-year locust (cicada). Another species, *Diceroprocta vitripennis* Say (= *Cicada erratica* Osborn) was reported by Newell (1906) as doing serious damage to cotton over a large area in the Onachita Valley, Louisiana. On one plantation of several hundred acres the crop was so seriously damaged that replanting was necessary and on another the damage was estimated at 20 per cent of the crop. In this case the plants were damaged exclusively by the female cicada puncturing the stems and twig for egg deposition; no feeding was observed at all. Corn plants in this vicinity were also seriously damaged from egg punctures in the stalk bearing the tassels. Such injury usually resulted in the death of the tassel and thereby destroyed the pollen.

Various other species in different parts of the country have at times caused more or less serious damage to fruit trees and other plants. Cooley (1911, 1912) reports *Okanagana cruentifera* (Uhler) (=Cicada) as producing considerable damage to fruit trees in the Bitter Root Valley, Montana.

Brittain (1914) reports *Platypedia putnami* (Uhl) (= Cicada) injurious to apple trees. He states: "These insects appeared in large numbers this year and were responsible for a certain amount of damage to the apple trees by ovipositing in the twigs."

The citrus cicada, *Diceroprocta cinctifera* (Uhler) (= Cicada), was reported by Glick, 1923, as doing considerable damage to citrus in Arizona. Many of the small twigs die from the effect of the oviposition injury.

In the Coachella and Imperial valleys, California, *Diceroprocta apache* Davis breeds commonly in the mesquite thickets but readily adapts itself to live on cultivated plants. The small twigs of grapefruit trees sometimes die from oviposition wounds and the leaves of the date palms often snap off near the tips where the cicada egg punctures are numerous. Some damage is also inflicted on stems of asparagus plants growing on recently cleared land.

Two species of small cicadas, *Platypedia areolata* Uhler and *P. minor* Uhler, sometimes reach destructive proportions in their oviposition in fruit trees in the coastal areas of Central California. The former species sometimes becomes so abundant in a couple of prune orchards near Edenvale, Santa Clara County, that they rise like a swarm of flies when the trees are suddenly disturbed and during a season of such abundance scarcely a twig of year-old wood escapes the thrusts of the cicada ovipositor. While I have not seen *P. minor* quite so numerous as *P. areolata*, they do however become rather abundant in prune or plum orchards in the Vaca Valley, California, and lay their eggs in the year-old wood. Both species will oviposit and feed on a number of different plants and both show a decided preference for prune or plum trees. Besides a certain amount of pruning resulting from oviposition, the scars offer easy entrance to fungous spores and are evident on most trees for several years.

Clidophleps distanti Van D. seems also to prefer yeàr-old apricot wood in which to oviposit and at times the damage has been quite noticeable in the Sacramento Valley, California. It also has been seen to oviposit in grapevines and cherry trees as well as various native plants. Among numerous other species damaging cultivated plants by oviposition, the following are mentioned:

Cicada orni Linn occasionally damage fruit trees in Italy.

Tibicen ochracea (Walk.) and *Moganni hebes* (Walk.) cause some injury to mulberry in Japan and the latter is injurious to sugar cane.

Marcrotristria angularis (Germ.) and *Cyclochila australasiae* Don. are reported as damaging peaches and a *Melampsalta* sp. as ovipositing in vines in Australia.

Transmission of Disease.—While there has been no definite proof that cicadas transmit plant diseases there are certain instances where the evidence seems rather convincing that they are vectors. In regard to

Tibicen davisi S. and B. nymphs causing injury to the ferneries in Florida, Wilson (1930) states that they suck the "plant juices from the roots which gradually turn dark and lose all the lateral feeders. In the case of plants which are severely injured the entire root system dies back to the crown. At this time the effect becomes decidedly noticeable above ground as the plant begins to turn brown and die back." This type of injury to the roots of the asparagus plants seems more than that produced by just sucking out the plant juices for they are reported as feeding on the roots of various other plants but no similar injury is evident. *Diceroprocta apache* Davis presents a similar case where the nymphs are numerous about the roots of asparagus plants in the Coachella Valley, the plants do not grow well and after struggling along for a season or two die out completely. In January, 1932, the writer observed this type of injury on several fields near Indio and it was claimed by one grower that there were about 1200 acres thus affected. When some of the full grown nymphs from this area were placed on the roots of an alfalfa plant within about two weeks the leaves began to take on a mottled appearance and within ten days more the whole plant wilted down and was completely destroyed. This reaction certainly could not have been produced merely by sucking out the sap from the roots but strongly indicates that some organism may have gained entrance through the feeding punctures of the cicada nymphs.

CICADA CONTROL.—Little effort has been expended in the control of cicadas other than for the periodical cicada and two or three other species.

In general, for the control of the periodical cicada it is recommended that the grower avoid planting out young trees in the vicinity of wooded areas or old orchards a year or two prior to an expected emergence of the periodical cicada. Also, all pruning operations on older trees during the winter and spring, prior to the expected emergence, should be deferred until after the danger is past in order to offer a larger twig growth for oviposition and thus distribute the damage over a greater surface.

Handpicking of the adults early in the morning when they are sluggish; dusting with pyrethrum kill freshly emerged adults and kerosene emulsion destroys many nymphs.

Trees thoroughly sprayed with Bordeaux mixture, lime-sulfur, or whitewash are apt to be avoided by the cicadas, especially if there are other trees nearby in which they can oviposit. Tobacco dust incorporated in the soil or the injection of carbon disulfide was found by Marlatt (1907) to be effective against the nymphs.

Wilson (1930) found carbon disulfide emulsion partially effective

against the nymphs of *Tibicen davisi* but did not kill the 5th instar nymphs. Other materials, such as various strengths of calcium cyanide, Black Leaf 40, carbolic acid emulsion, a number of pyrethrum compounds, chloride of lime, kerosene emulsion, Mowrah Meal (a fertilizer), steam, hot water, and carbon disulfide all proved ineffective against the nymphs of this species.

The *Hydraulic Pressure Method* was developed by a grower in Florida who found it very effective against the nymphs of *C. davisi* in his fernery. The nymphs are fairly mined out from about the "fern" roots in the soil and left on the surface of the ground where they fall easy prey to birds and other animals or dry out and die. Some were hit and torn to pieces by the stream of water.

Since the eggs of this species were laid in the timbers of the "fernery," these were treated with Bordeaux mixture, lime-sulfur solution, whitewash, and various strengths of oil emulsion in an attempt to prevent the female cicadas from depositing their eggs in the dry wood over the plants. The area bearing the whitewash was the only one avoided by the cicadas.

In an attempt to control *P. areolata*, tree tanglefoot was placed on the trunk of some trees but this only aided the clinging propensities of the nymph while the winged adult emerged from the nymph skin.

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SOME METHODS FOR SHIPPING, FEEDING, AND REARING FRUIT-FLY PARASITES

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The Mediterranean fruit-fly (*Ceratitis capitata* Wied.) in Hawaii is parasitized by three opiine parasites, *Opius humilis* Silv., *Diachasma tryoni* Cam., and *Diachasma fullawayi* Silv., and by a small chalcid, *Tetrastichus giffardianus* Silv., all of which were introduced into the Islands in 1913–14. Records of parasitism by these insects over the 10 year period 1914–1924, published by the Bureau of Entomology, show their combined efficiency is adequate to produce a total parasitization of about 50 per cent of all the fruit-fly larvae. These records also show that about 4 years were required to reach this degree of parasitization, and that since then a fairly constant and continuing relationship has existed between fruit-fly population and parasitism. Willard (2) states that a total parasitization of 47.5 per cent was attained in 1917 and that between 1917 and 1924 the yearly percentage ranged between 38.2 and 56.4. Although the control effected by these parasites is not comparable to that obtained with parasites of a number of other insect pests in Hawaii, the general success with parasites in the Islands has stimulated interest in biological control in other parts of the world. As a consequence, many requests have been received for shipments of fruit-fly parasites to other localities for the control both of the Mediterranean fruit fly and of other insects. This paper records the results of some studies on methods of shipping, feeding, and rearing fruit-fly parasites.

SHIPPING METHODS.—Although the insects are shipped most easily in the pupal stage, and this method has been used in some instances for transferring these parasites to new localities, in other cases it has not been possible to ship them as pupae. The parasitized fruit-fly puparia cannot be segregated with any degree of certainty from those not parasitized, and hence the shipment of the supposedly parasitized puparia

into or through uninfested territory would be a dangerous procedure, and is therefore prohibited by plant quarantines. In addition, the range of temperature within which the pupae can survive over an extended period of time is rather limited. Because of their tropical origin, they are sensitive to low temperatures and, furthermore, their rapid development at normal temperatures precludes the possibility of sending them far without refrigeration. When held at 36°–41°F., the temperature ordinarily carried in the fruit and vegetable chambers of ships, puparia do not live long enough to permit movement of parasites. Mortality of the pupae during the first few days is high. Below 50° F. no development takes place in fruit-fly puparia, and extended subjection to such temperatures will prevent emergence and ultimately cause death. At temperatures between 50° and 60° F. there will be some development, but it is sufficiently delayed to permit shipment over long distances without severe mortality. From 35 to 50 days are normally required for emergence from pupae held at 55°–60° F. By the use of constant refrigeration at 60° F. several consignments of parasitized fruit-fly puparia have been successfully sent to Australia, a trip requiring about 17 days. Although one of the parasites, *Diachasma tryoni*, is indigenous to Australia, it was desired to introduce there also the three African parasites to assist in the control of the fruit fly in New South Wales. The parasitized puparia were packed in small cans containing dry sand or shredded paper to absorb moisture and prevent molding and were forwarded in the cool chamber of the ship.

The undesirability of sending living fruit-fly puparia into the United States and other uninfested territory has led to a study of methods for shipping the parasites in the adult stage. The low temperatures usually found on ships are also fatal to the insects in this stage. When they were held at temperatures of 36° to 41° F., the mortality was high after 6 to 7 days, less than 5 per cent surviving from several lots so treated. Several shipments of parasites to California (a trip requiring 6 days) at these temperatures resulted in almost complete failure. Between 44° and 50° F., however, the insects can be kept alive for extended periods of time. At these temperatures no feeding and little activity take place. Holloway (1) has successfully used refrigeration at 45° to 50° F. for the shipment of *Macrocentrus ancylivorus* Busck and other parasites of the oriental fruit moth (*Grapholitha molesta* Busck) on trips requiring up to 55 hours, with a mortality of only 1.4 per cent. The longevity of the adults was extended and no injury produced from exposure to such temperatures. The fruit fly parasites also show a remarkable longevity under such conditions, a maximum of 39 days' continuous holding being recorded

for *Opius humilis*. In the case of three collections of *Diachasma tryoni* totaling 125 individuals, final survivals of 18, 20 and 22 days occurred, with 50 per cent mortality after 10 to 15 days.

By the use of a system of alternate feeding and holding in cold storage, the longevity and percentage of survivals were materially increased. When removed from the cold room to room temperature and fed dilute honey for 24 hours at intervals ranging from 6 to 14 days, a large percentage of the adult parasites were maintained alive for several holding periods. Table 1 shows the results of a series of such holding tests on three parasites, *Opius humilis*, *Diachasma tryoni*, and *D. fullawayi*. In each test of the first two species 10 recently emerged adults were used in all feedings, but in the case of *D. fullawayi* 38, 40, and 26 individuals were used, respectively, for the 6, 8, and 10 day feeding intervals. The parasites were placed in glass tubes 2½ by 12 inches and kept in the constant-temperature room except during the feeding period. The time for 50 per cent mortality and the length of the longest survival for each lot are given in the table.

TABLE 1. MORTALITY RECORDS OF PARASITES HELD AT 44°–50° F., WITH FEEDINGS AT THE END OF INTERVALS RANGING FROM 6 TO 14 DAYS

Parasite	Feeding interval	Time of 50 per cent mortality	Maximum survival
	Days	*Days*	*Days*
Opius humilis	6	105	145
	7	144	151
	8	107	197
	9	141	150
	10	121	143
	11	120	131
	12	25	155
	13	125	166
	14	29	133
Diachasma tryoni	6	50	80
	7	34	55
	8	53	107
	9	59	71
	10	32	76
	11	37	49
	12	40	66
	13	13	41
	14	28	74
Diachasma fullawayi	6	48	90
	8	71	117
	10	20.	99

The figures in Table 1 show a remarkable longevity for the parasites, especially *O. humilis*. Fifty per cent mortality was not reached until more than 100 days had passed in several cases, and a final survival of

197 days is recorded for one individual. The longevity of *D. tryoni* was not so great, but in all cases where the feeding interval was 10 days or less the parasites were maintained with less than 50 per cent mortality for more than 30 days. This is also true of *D. fullawayi* with the exception of the lot fed at the 10-day interval, where 50 per cent mortality occurred after 20 days. These records indicate that shipments of the adult parasites under similar conditions on journeys requiring 30 to 60 days, or even longer in some cases, would be successful.

On removal to room temperatures, the parasites reacted normally in every respect. Neither was their vitality destroyed by the treatment, since oviposition tests with individuals held in storage for periods of 35 to 42 days showed that they were able to deposit fertile eggs and reproduce both sexes in approximately the same ratio as individuals subjected to normal temperatures.

At room temperatures (65° – 80° F.), with daily feedings, the longevity of the parasites was somewhat less than in the cold room. A lot of 10 *O. humilis* adults kept continuously under these conditions reached 50 per cent mortality after 64 days and the last individual died on the 84th day. In three lots of *D. tryoni* composed of 119, 50, and 50 individuals each, 50 per cent mortality was reached on the 42nd, 35th and 28th days and the last individuals died after 70, 70, and 84 days, respectively.

TABLE 2. MORTALITY RECORDS OF PARASITES HELD AT 44°–50° F. WITH FEEDINGS AT THE END OF EACH 6-DAY PERIOD

Parasite	Individuals	Food	Time of 50 per cent mortality	Maximum Survival
	Number		*Days*	*Days*
Opius humilis.....	21	Honey-agar	128	154
	50	Cube cane sugar	35	112
	131	Cube cane sugar	42	105
	60	Cube cane sugar	70	126
Diachasma tryoni....	150	Honey-agar	35	119
	44	Honey-agar	42	105
	34	Cube cane sugar	77	154
Diachasma fullawayi..	16	Cube cane sugar	63	105
	8	Honey-agar	70	154

With proper care the adults can be kept alive for many weeks, and they have been carried for long distances when cared for personally enroute. The original importations into Hawaii from Africa and Australia were made in this way, and the first shipment of parasites made by the Bureau of Entomology from Hawaii to Spain in 1931 was successfully accomplished by this method. In the latter case the insects were kept at room temperatures and fed each day during the journey, and after a trip

of more than 30 days' duration 137 of the original lot of 1700 parasites reached Spain in good condition.

The results of some additional tests on larger numbers of parasites held in the cold room in copper or monel wire screened cages are shown in Table 2. In all these tests the insects were removed from the cold room at 6-day intervals and fed for 24 hours.

The results here confirm those shown in Table 1 when only 10 individuals were used, with glass tubes for containers. In all cases the time of 50 per cent mortality is shown to be 35 days or more. As in the tests recorded in Table 1, *Opius humilis* shows the greatest longevity.

FEEDING METHODS AND LONGEVITY OF PARASITES.—The food that has been found most satisfactory for maintaining adult parasites in the laboratory is a dilute honey solution (1 part of strained honey to 2 parts of water). By means of a camel's-hair brush small droplets of this material are placed on either a fresh leaf or a sheet of paraffined paper and inserted into the cage. No additional water is necessary. Other satisfactory foods are cube cane sugar, a nearly dry mixture of honey and powdered cane sugar, and honey-agar made stiff enough to keep it from melting and becoming sticky (1 gram of agar-agar, dry weight, to 50 cc. of dilute honey solution). Any of these last named foods can be used in cages for shipment. It is, of course, necessary to supply water also, and this can be done by means of a self-feeding bottle. Care must be taken to avoid excessive humidity in the cages, as this will cause the honey or sugar to become sticky and the insects may become stuck in the food. The relative values of these foods for sustaining the parasites are shown in Table 3. These results were obtained from confining 10 recently emerged adults of *Opius humilis* and *Diachasma tryoni* in small screened cages in the laboratory.

TABLE 3. RELATION OF FOODS TO LONGEVITY OF *Opius humilis* AND *Diachasma tryoni* AT ROOM TEMPERATURE (65°–80° F.)

Food	*Opius humilis*		*Diachasma tryoni*	
	Time of 50 per cent mortality	Maximum survival	Time of 50 per cent mortality	Maximum survival
	Days	*Days*	*Days*	*Days*
Diluted honey...	41	116	27	39
Cube cane sugar and water.....	48	75	20	45
Honey-agar and water.....	37	65	14	50

No outstanding difference in the value of the various foods is shown in the results. As in the experiments recorded in Tables 1 and 2, the longevity of *O. humilis* is greater in every case than that of *D. tryoni*.

METHODS OF REARING PARASITES.—For rearing the opiine parasites in the laboratory small cages must be used so that the insects will be in close contact with infested fruits. Oviposition will readily take place under such conditions. Well-developed maggots in small fruits placed in the cage will be well parasitized after 24 hours' exposure to the parasites. The fruits should then be removed and held over sand until the maggots have emerged and pupated. *Tetrastichus giffardianus* adults, when placed in a small tube with mature fruit-fly maggots, will attack and parasitize them direct, but the opiine parasites will only parasitize the maggots that are in the fruits.

Failures in establishing parasites are often due to improper handling of the insects after their receipt. Rearing them under laboratory conditions in order to increase the stock sometimes results in the entire supply dying out. Although several generations of fruit-fly parasites can be reared in cages under such conditions, there is a tendency for only males to be produced after a few generations. Hence it is usually advisable to liberate under natural conditions at least a part of any lot of parasites introduced. A large screened cage over a tree containing infested fruits will serve the purpose of producing natural conditions and at the same time keep the parasites where they can be recovered.

SUMMARY.—The results of the experiments recorded here show that the fruit-fly parasites have a remarkable longevity and may be transported for long distances under proper conditions of feeding and shipping. At room temperatures adult parasites can be kept alive for several weeks when provided with proper food. They are able to withstand refrigeration at 44°–50° F. for 10 days without food or for many weeks if removed from the cold room to room temperatures and fed at intervals of 6 to 10 days. This makes possible their shipment with little care or expense en route provided suitable refrigeration is available. Parasitized pupae can be held at 55°–60° F. for 35 to 50 days before any emergence takes place and with little mortality. Storage at ordinary food-refrigeration temperatures (36°–41° F.) will prove fatal to a large percentage of both pupae and adults after a few days.

The methods described have been successfully used with several consignments of adult parasites sent from Hawaii to California, the mortality in some cases having been less than 10 per cent. Similarly, living adults have been introduced into Spain from Hawaii by using cold-storage holding on ships together with air transportation across the continent. Several successful shipments of parasitized fruit-fly puparia have been sent to Australia.

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EFFECT OF LOW TEMPERATURES ON THE MEDITERRANEAN FRUIT FLY IN INFESTED FRUIT

By A. C. MASON and O. C. MCBRIDE, *Bureau of Entomology, United States Department of Agriculture*

This paper is a preliminary report of the results of certain tests carried on at the Honolulu laboratory of the Bureau of Entomology to determine the time-temperature values necessary to insure mortality within the fruits of all living stages of the Mediterranean fruit fly (*Ceratitis capitata* Wied.)[1]

REVIEW OF LITERATURE.—The application of low temperatures to the control of larvae of the Mediterranean fruit fly first received attention in Africa and Australia, where growers sought European markets for their surplus fruit. In 1907 Lounsbury (*3*) conducted experiments to determine the practical value of low temperatures for the treatment of infested fruits. He found that a temperature range of 38°–40° F., continued for 3 weeks, was sufficiently low to insure death to all fruit-fly larvae in infested peaches, that treatment for 2 weeks gave a high mortality, but that after 1 week at this temperature range the maggots were not killed. In a later paper (*4*) he reported experiments with infested peaches in which there were no survivals from 511 larvae exposed at 38°–40° F. for 21 to 27 days.

Hooper (*6*), in Western Australia, found that eggs and larvae of the fruit fly succumbed within 15 days at 33°–35° F. He stated the exposure of fruits for 3 weeks to this range of temperature would insure the destruction of all living forms.

In 1916 Back and Pemberton (*1*) reported on a large series of cold-storage experiments in which they found that no eggs or larvae of the Mediterranean fruit fly in apples (*Malus* spp.), peaches or kamani nuts (*Terminalia catappa*) survived exposure to 40°–45° F. for 7 weeks, 33°–40° F. for 3 weeks, or 32°–33° F. for 2 weeks.

In 1923 Mally (*5*) reported that fruit-fly larvae in stone fruits, wrapped and packed in wood wool, survived 6 weeks' refrigeration at

[1]Acknowledgment is made to Mr. W. W. Yothers for some of the early experimental work in Hawaii.

temperatures fluctuating between 25° and 44° F., with a mean of 33.97° F. He noted that larvae in individual fruits were either all dead or all alive and advanced the hypothesis that the packing material resulted in a gradual cooling of the fruit, and that the mortality was due to abrupt transition from high to low temperatures rather than to holding at a constant low temperature.

Petty and Griffiths (*4*) in 1931 published results of cold-storage tests on infested grapes, pears, and certain stone fruits at temperatures of 28°–34° F., with a maximum fluctuation of 3° F. In their experiments all larvae and pupae in infested fruits in trays, wrapped and packed for export, were killed when held continuously for 3 weeks at 32° F. In their 1929 studies at 30° F. mortality of all larvae and pupae was obtained in 7 days, but in their 1930 tests 11 larvae survived from 613 specimens exposed for 7 days, and 2 adults emerged from this lot.

Experimental Procedure.—The experiments reported here were conducted on a fairly large scale and under conditions simulating those encountered in the commercial handling of fruits. The object was to determine any possible survivals from large populations of fruit-fly eggs and larvae after exposure to low temperatures. Some of the experiments were conducted in large rooms in a local cold-storage plant and others in the laboratory cold room. At the cold-storage plant the temperatures of the rooms were maintained practically constant at 28°, 29°, 30° and 31° F., but in the laboratory cold room there was a fluctuation of ± 1° F. from any desired temperature during periods of about 2½ hours. There was, however, little, if any, variation in the interior of the fruit after it reached the temperature of the surrounding air. The time required for the interior of the fruit to reach room temperature ranged, according to the variety, from 18 to 48 hours.

In most cases naturally infested fruits containing large populations of larvae were collected in the field. In addition apples, oranges, and avocados were allowed to become infested in jars or cages in the laboratory. The fruits were counted out into equal-sized samples and placed in trays, 12 by 14 by 3 inches, with a bottom of ¼ inch mesh wire screen. These trays of fruits were then taken to the cold room for exposure to the desired temperature. One or more trays, selected at random, were kept out for checks in order to determine the exact larval population of the fruits. This record was obtained by holding the trays of fruits in the insectary over a box of clean sand, into which the mature larvae after emerging from the fruits would drop and pupate. By sifting the sand at 7-day intervals all the pupae were recovered and counted. This number served as a basis for estimating the population of larvae in the treated lots.

After the infested fruits had been held in the cold room for the desired length of time, they were removed to the laboratory or insectary in order to determine the number of survivals. This was accomplished by one of two methods. Either the fruits were dissected and the larvae in them examined for signs of life, or the fruits were held in the insectary over sand, as were the check lots described above, and any surviving larvae or pupae recovered by sifting the sand.

In the former method all living or doubtful larvae found in the dissected fruits were removed to a slice of fresh papaya or other fruit and held under daily observation to determine their ability to complete development. This examination gave an accurate count of the number of larvae recovered from the fruits but failed to disclose the presence of all larvae in them. It showed that there is an initial survival of larvae, many of which later die before reaching maturity. As a method of determining the effect of low-temperature exposure on larvae, however, it has many disadvantages and was later discontinued in favor of the holding method. The danger of mechanical injury to the larvae in handling; exposure to light and air, causing desiccation and possible injury to the maggots; and the change of food and environment due to removal are all factors tending to kill larvae that might complete their development if allowed to remain undisturbed in their natural environment.

By the method of holding the fruits over sand surviving larvae may continue feeding undisturbed in their natural environment within the fruits, emerge on completion of their development, and pupate in the sand beneath the tray, where they can be recovered. This is believed to be a more natural and practical method of determining the effects of low temperatures on fruit-fly larvae. Although much labor is involved in handling the large numbers of fruits, the records obtained on large populations handled in this way give evidence of the effectiveness of the treatment.

The mortality percentages are based on the number of pupae obtained from surviving larvae. Although the studies have shown that some larvae can survive for several days after exposure to fatal low temperature, but without being able to pupate, such larvae were not counted as survivals since they could never be a source of danger from an economic standpoint. Many of the pupae exposed to cold are also unable to develop into adult flies, and this still further reduces the percentage of ultimate survivals and increases the safety of recommendations based on the experimental results. The count of pupae has been adopted, however, as the most accurate method of determining the efficiency of the treatments.

RESULTS.—The data in Table 1 are based on the results of 130 experiments in cold-storage holding, in which a total of 133,773 fruits, containing a total population of 550,925 eggs and larvae of the Mediterranean fruit fly, were used. The mortality percentages are shown only for each day from 7 to 11 days. For the lower temperatures the time for complete mortality ranged from 18 hours at 10° F. up to 7 days at 27.50° F. Only a limited number of experiments were performed at these lower temperatures, however, since they are below the range of practical storage temperatures for fruits. The work was centered around 30° F., with the greatest number of experiments performed between 29° and 31° F. Although little variation in the mortality percentages is shown between these two limits, the actual number of pupae surviving increased as the temperature was raised. The time for 100 per cent kill of larvae is shown to range from 8 to 11 days at these temperatures.

TABLE 1. MORTALITY OF MEDITERRANEAN FRUIT-FLY EGGS AND LARVAE IN INFESTED FRUITS AFTER EXPOSURE TO TEMPERATURES RANGING FROM 10° TO 31° F. FOR VARIOUS PERIODS

Temperature °F.	Tests *Number*	Fruits *Number*	Eggs and larvae *Number*	Mortality after 7 days *Per cent*	8 days *Per cent*	9 days *Per cent*	10 days *Per cent*	11 days *Per cent*
10	2	2,550	6,251	100	100	100	100	100
20	3	3,675	7,369	100	100	100	100	100
21	1	192	642	100	100	100	100	100
21.5	1	700	1,385	100	100	100	100	100
22.5	1	1,300	2,041	100	100	100	100	100
23	1	342	749	100	100	100	100	100
24	1	1,450	4,095	100	100	100	100	100
27.5	5	3,610	22,369	100	100	100	100	100
28	4	3,491	22,910	99.9	99.9	100	100	100
29	20	12,395	45,320	99.9	99.9	99.9	100	100
29.5	11	22,660	62,388	99.9	100	100	100	100
30	22	14,660	34,630	99.4	99.8	99.9	100	100
30.5	19	23,580	175,106	99.9	99.9	99.9	100	100
31	39	43,168	143,490	99.7	99.8	99.9	99.9	100
Total	130	133,773	550,925	—	—	—	—	—

EFFECT OF FLUCTUATION OF TEMPERATURE ON MORTALITY.—Because of the adjustable range and differentials of thermostat control in most cold-storage plants, constant temperatures can rarely be maintained. In addition, the movement of fruits in and out of storage rooms in commercial plants often causes a variation of several degrees from the mean for short periods of time. In order to determine the effect of such variations on the survival time of fruit-fly larvae in fruits, a series of tests were planned in which various temperatures above the desired point were used during a part of the holding period. For this experiment 8,674 fruits of several different kinds, containing 102,473 eggs and larvae, were employed. Of this number, 32,101 insects held at a constant tem-

perature of 31° F. for 6 to 15 days, as a check on the other experiments, showed no survivals after 9 days. The remainder of the fruit was divided in several lots, which were moved from the 31° room into the 34°–35° room for varying lengths of time, such as 6 hours during each day of the holding period, 24 hours continuously on each alternate day, and continuous holding for from 1 to 5 days during the entire period. But little difference was noted between the results for fruits held at a constant temperature of 31° F. and those in which the temperature was varied. The experiment showed that raising the temperature of the infested fruits 3 or 4 degrees above 31° for a part of the holding time had little effect in prolonging the life of the insects contained therein, provided they were first cooled to the lower temperature. In all cases the mortality was 100 per cent after 8 to 11 days.

DISCUSSION OF RESULTS.—The results of these experiments, covering in all the use of more than half a million eggs and larvae of the Mediterranean fruit fly, show that complete mortality in infested fruits was obtained after 8 to 11 days' exposure at temperatures of 29° to 31° F. These results support for the most part the findings of other workers, as reported above. Moreover, small variations in temperature above the prescribed point for a part of the holding period are shown not to prolong materially the life of the insects. While the work discussed here covers experiments only below the freezing point of water and shows the time for complete mortality to range from 18 hours at 10° F. up to 11 days at 31° F., the results conform with those of Back and Pemberton (*1*), who obtained survivals of 6 larvae from a total of 332 third-instar larvae treated at 32° F. for 11 days but no survivals from 626 third-instar larvae treated at 32° F. for 12 to 15 days. As the temperature was raised the time for complete mortality increased until 46 days were required at 40°–45° F.

The time-temperature values as given in the results of these experiments are well within the limits of practical storage for many fruits under commercial conditions. The experiments indicate also that the treatment of infested fruits under those conditions will insure their freedom from any living form of the Mediterranean fruit fly.

EFFECT ON FRUITS.—The commercial application of the method necessitated that observations also be made on the effects of the cold treatment on the fruits. In many of the fruits used in the experiments little injury was noted. The infested fruits were often overripe when placed in storage and hence would break down rapidly when returned to normal temperatures. However, fruits that were firm and solid at the time of entering storage usually withstood the treatment at 29° to 31° F.

for 10 to 15 days without serious injury. This was particularly true of juicy fruits, such as citrus fruits, guavas, and mangoes. Some of the smaller, less juicy fruits, such as kamani nuts, coffee berries, and loquats, had a tendency to turn brown and have a scalded appearance after several days in the cold room. Among the fruits of commercial importance the only one seriously affected by the cold treatment was the avocado. Regardless of the stage of maturity, the flesh of the avocado became discolored and bitter after several days' exposure at temperatures around 30° F.

Summary.—Complete mortality of all immature stages of the Mediterranean fruit fly was obtained after infested fruit had been held for 8 to 11 days at internal temperatures of 29° to 31° F. Citrus fruits, mangoes, and guavas were not seriously injured when held at these temperatures for the period of the experiments. The time for complete mortality of all stages of the fruit fly was shown to range from 18 hours at 10° F. up to 11 days at 31° F.

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THE EFFECT OF SUBFREEZING TEMPERATURES ON THE MANGO WEEVIL

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The problem of fatal low temperatures and the resistance of insects to cold has been under considerable discussion in recent years. It has been of interest not only from the theoretical viewpoint of cold-hardiness, but also because of the relation to climatic control in nature and its practical value in eliminating living stages from material that may be moved in commerce. This paper records the results of some studies on the effect of

subfreezing temperatures on the mango weevil (*Sternochetus mangiferae* Fab.) in Hawaii. The weevil attacks the seed embryo of the young fruits. The newly emerged larvae enter through the flesh from eggs laid on the surface of the green fruit, and here they remain throughout their development to adults, feeding on the contents of the seeds. The flesh of the fruit is not directly attacked, the injury to the fruit consisting in premature dropping and a softening of the flesh around the seeds. Since the weevil spends its entire life cycle on or within the fruit, all stages of the pest may be readily moved with fruits entering commerce or with seeds transported for propagation purposes. The object of these studies, therefore, was to determine the lower fatal time-temperature exposures required to kill the different stages of the mango weevil within the seeds.

METHODS.—The various stages of the insects were exposed in naturally infested mango seeds to temperatures of 10°, 20°, and 30° F. Fresh fruits were collected in the field, and after the flesh had been removed the seeds were arranged in trays of 100 each and placed in the cold room for varying lengths of time. Although the temperature of the room fluctuated 1.5° F. during intervals of about 2½ hours, the temperature of the seed seldom varied more than 0.1° F. At the end of the exposure period the seeds were removed from the cold room and allowed to dry for 2 to 3 days, after which they were cut and examined for living material. A record was made of all living and dead specimens, and any doubtful specimens were placed in small vials and held for 2 weeks with periodical examinations to determine the mortality.

RESULTS.—It was found that the number of weevils per seed ranged from 1 to 6 and the percentage of seeds infested in each sample ranged from 13 to 88.

The results of the tests are recorded in Table 1. An analysis of the data shows that the mortality of all stages of the weevil increased directly with length of exposure to low temperature, as well as to degree of cold. At 10° F. 24 hours' exposure killed 30.5 per cent of the adults and 50 per cent of the pupae, while 48 hours' exposure killed all the larvae and pupae but only 77.7 per cent of the adults. The mortality percentages of the adults increased daily up to 5 days, when 100 per cent were killed.

At 20° F. much longer survivals were recorded for all stages of the weevil. A decided difference was noted also in the results of experiments run at this temperature on infested seeds collected in August and in October-November. In August an exposure of 6 days at 20° F. killed 33.3 per cent of the adults and the percentage gradually increased until the fourteenth day, when no survivals were found. In October and November, however, the results show that the adults were more resistant

TABLE 1. MORTALITY OF MANGO WEEVILS IN SEEDS SUBJECTED TO SUBFREEZING TEMPERATURES FOR VARIOUS PERIODS OF TIME

Exposure: Temperature	Month of Collection	Period	Mortality: Larvae	Pupae	Adults
		Days	*Per cent*	*Per cent*	*Per cent*
10° F.	October	1	100	50	30.5
		2	100	100	77.7
		3	100	100	89.2
		4	100	100	96.9
		5	100	100	100.
		6	100	100	100.
		7	100	100	100.
		8	100	100	100.
20° F.	August	6	100	93.7	33.3
		7	100	100	50.0
		8	100	100	62.5
		9	100	100	55.5
		10	100	100	66.2
		11	100	100	63.3
		12	100	100	57.2
		13	100	100	91.6
		14	100	100	100.
		15	100	100	100.
20° F.	September	2	82.2	50	27.3
		3	100	94.1	45.8
		4	80.6	73.3	47.6
		5	85.7	100	46.6
		6	100	100	65.4
		7	100	98.6	79.7
		8	100	100	86.3
		9	100	100	85.3
		10	100	100	73.0
		11	100	100	72.9
		12	100	100	85.3
		13	100	100	80.1
		14	100	100	89.2
		15	100	100	96.8
		20	100	100	96.0
		25	100	100	100.
		30	100	100	100.
20° F. cont.	October-November	10	100	100	35.5
		12	100	100	75.0
		14	100	100	83.3
		16	100	100	87.0
		18	100	100	96.9
		20	100	100	96.3
		22	100	100	95.6
		24	100	100	100
		26	100	100	100
		28	100	100	100
30° F.	October-November	5	33.3	100	26.7
		10	75.0	66.7	33.3
		15	83.3	66.7	37.5
		20	71.4	66.7	25.0
		25	75.0	——	33.3
		30	100	100	30.0
		35	100	60	37.5
		40	100	100	38.5
		45	100	100	91.1
		50	100	100	84.7

than those collected in the summer and early fall. Ten days' exposure of the September material produced 73.3 per cent mortality of the adults, while late in the fall adult mortality was only 35.5 per cent. About 4 per cent of the adults even survived 20 days in fruit collected in September and 22 days in the late fall material. However, after 24 days no adults in any of the lots were able to survive. The larvae and pupae showed less resistance to cold than the adults. Exposures at 20° F. for 8 days killed all pupae while 6 days was sufficient to kill the larvae.

At near freezing temperatures all stages of the mango weevil were capable of surviving long exposures. The data show that 73.3 per cent of the adults survived 5 days' exposure at 30° F., 66.7 per cent survived 25 days, and 15.3 per cent survived 50 days' exposure. The tests were not continued beyond 50 days. The pupae were able to survive this temperature for 35 days, but none survived 40 or more days. All larvae were killed after an exposure of 30 days at 30° F.

DISCUSSION.—In addition to indicating the time-temperature limits at which all stages of the mango weevil were destroyed, these studies show some interesting characteristics of the insect with regard to cold-hardiness. Although a tropical species, the mango weevil exhibted many of the characteristics recorded in this respect for plants and insects of the Temperate Zone. Under natural conditions the mango weevil in Hawaii is not subjected to extremes of temperature, the maximum throughout the year seldom exceeding 85° F. and the minimum seldom falling below 58° F. As a result the weevils are active during most of the year but usually enter hibernation during the off-fruit season, which extends from September to January. In normal seasons the fruits susceptible to weevil infestation are present on the trees from early in February to July, with an occasional late variety extending into September or later.

The data show a marked difference in the ability of individuals of the same developmental stage to withstand prolonged exposure to low temperatures and also in the resistance of the different stages to cold. At 10° F. individual adults of the mango weevil survived from 1 to 5 days, while in the case of the pupae and larvae the range was only from 1 to 2 days. At 20° F. the minimum time for adult survival was 1 day while the maximum was 22 days. For pupae the minimum time was 1 day and the maximum time 8 days, while in the case of larvae the first individual died after an exposure of 1 day and the most resistant individual survived for 5 days. The data show proportionate variations for both individuals and stages in the experiments at 30° F.

It was also found that the mango weevil exhibited a seasonal variation in cold resistance. All the adults collected in August succumbed to

20° F. in 14 days, while in the October-November collections 24 days' exposure was required for complete mortality.

A review of the literature has shown similar phenomena to have been recorded by workers on other species of insects. Although the relationship of freezing and cold-hardiness was first recognized in the plant group, Knight (*3*) and Gueylard and Portier (*2*) later pointed out the seasonal variability in cold resistance of insects. The French authors, working with *Cossus cossus* L., found that the insects survived repeated exposures at —20° C. in winter but in the spring succumbed to —17° C. Knight, working with *Perillus bioculatus* Fab., supercooled the insects in winter to —17° C. without freezing, but in March or later —10° C. was sufficient for death. Similar conditions were noted in the wood borers by Payne (*4*). The same author (*5*) further found that cold-hardiness of the Japanese beetle could be induced by partial dehydration or increased by starvation and decreased by an abundance of fresh food. Back and Cotton (*1*) found that the susceptibility to low temperatures of *Sitophilus oryza* L. and *S. granarius* L. varied so much in individuals of the same species that conclusions regarding fatal low temperatures must be based on work with large numbers. Robinson (*6*, *7*) reported a direct correlation between cold-hardiness and the quantity of bound water. Sacharov (*8*) found that the hibernating caterpillars of the brown-tail moth (*Nygmia phaeorrhaea* Don.) withstood —17.35° C., while as many as 82 per cent of the active caterpillars succumbed at —7.8° C.

The work of these authors and others shows that insect resistance to cold varies with species, individuals of the same species, and the season. In the case of insects in the Temperate Zone resistance to freezing may be induced by partial dehydration, starvation, gradual subjection to low temperatures, hibernation, and the quantity of free water in the tissue, while increased activity and abundance of fresh moist food decreases cold resistance. Apparently, under natural conditions the fatal point depends largely on the physiological condition of the insects, which is not constant for any given species or individual of the same species.

In the case of the mango weevil, it appears plausible to assume that inactivity, cessation of feeding, and hibernating tendencies produce physiological changes within the body. These changes, though less pronounced, are similar in character to those occurring in species inhabiting colder regions and may explain the seasonal variation in cold resistance.

SUMMARY.—Although the physiological effects of freezing were not considered in these studies, the data obtained show that the mango weevil, though living normally under more equable temperature condi-

tions, exhibits cold-hardiness characteristics similar in many respects to those of insects in the Temperate Zone.

When subjected to time-temperature values near the fatal point, a difference in cold hardiness is shown both between individuals of the same developmental stage and between stages. Further, the data show a seasonal difference in cold-hardiness.

Practical measures in low-temperature control necessitate exposures sufficient to be fatal to the most hardy individuals. The results indicate that this point is attained after 5 days' exposure at 10° F. and after 25 to 30 days' exposure at 20° F. Fifty days' exposure at 30° F. failed to result in complete mortality.

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RELATION OF OVIPOSITION PUNCTURES OF THE MEDITERRANEAN FRUIT FLY TO THE PREMATURE DROPPING OF CITRUS FRUITS

Preliminary Report

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In a test to determine the relative susceptibility of different varieties of citrus fruits to attack by the Mediterranean fruit fly, *Ceratitis capitata* Wied., samples of different varieties of fruit were taken at 10-day intervals through the fall and winter season and held for infestation records. By the time the third sample was taken all the fruits had fallen from the trees and had decayed immediately. It was also noted that a high percentage of the fruits had been punctured by female fruit flies in attempts at oviposition. The experiments were conducted in the United States Department of Agriculture Experiment Station grove at Honolulu. W. T. Pope, Senior Horticulturist, stated in conversation that "The greatest injury caused by the Mediterranean fruit fly to citrus fruits in Hawaii is the premature ripening and dropping of the fruits due to oviposition punctures." Back and Pemberton[1] state that, "If citrus fruits were grown commercially in Hawaii in large orchards as they are in Florida and California, and were severely attacked as they are in Hawaii today, they could not be shipped profitably, for, although they might not contain larvae within the pulp, the many breaks in the rind made by the flies while laying eggs would make possible the entry of various molds that would cause unprecedented decays while the shipments were en route to market."

After seeing the entire citrus fruit crop at the experiment station grove drop to the ground and decay within 40 days from the time it began to ripen, the question arose as to what it would mean from an economic point of view if the millions of boxes of fruit produced in the United States had to be picked and put on the market within 40 days after the fruit begins to ripen. At present fruit is held on the trees after it begins to ripen and is marketed over a period of several months, thus avoiding the expense of storage and lengthening the marketing season.

It was also noted that Chinese orange or calamondin fruits on a tree that had been screened for oviposition tests continued to remain on the tree, whereas fruits on unscreened trees dropped off early in the ripening season, or several months before fruits dropped from the screened tree,

[1]Back, E. A., and Pemberton, C. E. The Mediterranean Fruit fly. U. S. Dept. Agr. Bull. 640, 43 pp., illus. 1918. (See pp. 23–24).

and decayed. Although the fruits on the screened calamondin tree began to ripen in October and November, about 3,000 fruits were picked from the tree in June of the following summer and placed in cold storage.

The observations cited above suggested that in those sections with high humidity, where diseases of citrus fruits which would cause premature dropping are prevalent, the damage caused by the Mediterranean fruit fly due to oviposition punctures would amount to practically 100 per cent, regardless of the actual percentage of fruits infested. It appeared, therefore, very desirable to study the effect of oviposition punctures of the Mediterranean fruit fly on the premature dropping of citrus fruits.

DESCRIPTION OF EXPERIMENT.—An experiment was started in which a Duncan grapefruit tree and a Valencia orange tree were screened and

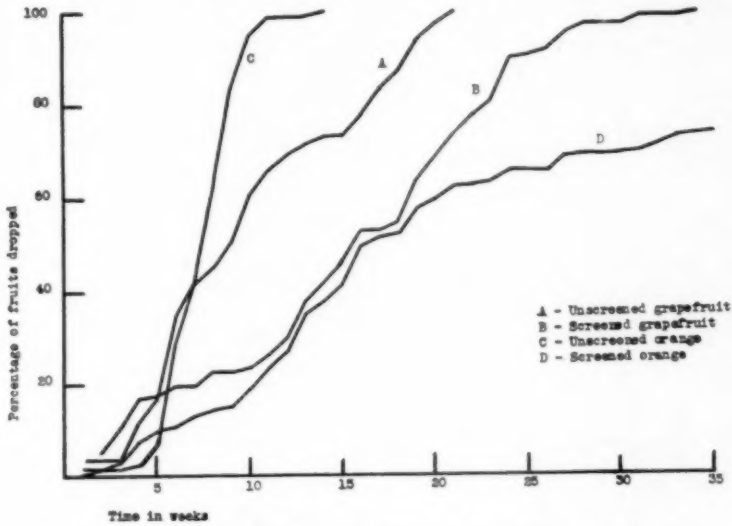

FIG. 92.—Rate of dropping of citrus fruit from screened and unscreened trees.

fumigated just before the fruits began to ripen in the fall. Small trees were used in the experiment to keep down the cost of screening. An adjacent unscreened tree of each variety was marked as a check and weekly counts were made of the drops under each tree. Table 1 gives the results of dropping of the fruits from the screened and unscreened trees.

Table 1 shows that practically all the fruits had dropped from the unscreened trees by February 1, while only 26.1 per cent of the fruits had dropped from the screened grapefruit tree and 23.3 per cent had

dropped from the screened orange tree. There were some late-bloom fruits on the unscreened grapefruit tree, which lengthened the time that fruits remained on it.

TABLE 1. COMPARISON OF FALLEN CITRUS FRUITS FROM SCREENED AND UNSCREENED TREES

Date		Fallen fruits from Grapefruit		Fallen fruits from Orange	
		Screened *Number*	Unscreened *Number*	Screened *Number*	Unscreened *Number*
	1931				
November	16	0	5	4	2
	23	6	0	0	2
	30	5	0	3	2
December	7	7	10	9	1
	14	1	5	6	13
	21	2	24	2	30
	28	0	10	5	34
	1932				
January	4	3	4	2	42
	11	0	7	2	54
	18	1	13	8	69
	25	3	7	10	38
February	1	4	4	8	9
	8	3	3	17	2
	16	4	2	7	0
	23	5	0	8	0
March	1	7	6	18	2
	8	0	7	4	0
	15	2	5	1	0
	22	10	9	11	0
	29	5	4	5	0
April	5	6	4	6	0
	12	4	0	1	0
	18	3	0	1	0
	25	10	0	6	0
May	2	1	0	0	0
	9	1	0	0	0
	16	4	0	0	0
	22	2	0	1	0
	31	0	0	0	0
June	6	0	0	1	0
	13	2	0	1	0
	20	0	0	4	0
	27	0	0	2	0
July	5	1	0	2	0
	11	0	0	1	0
Total		102	129	156*	300

*Fifty-seven fruits, or 26 per cent, were left on the screened Valencia orange tree on July 11, 1932.

In comparing the dropping of fruits from the unscreened grapefruit and orange trees (Fig. 92) it appears that the Valencia orange fruits (curves C and D) are affected more by the presence of the fruit fly than are the Duncan grapefruits (curves A and B). This, however, is not true. The unscreened grapefruit tree had some late-bloom fruits on it, which were not susceptible to fruit fly punctures until about the fifteenth week.

This should also be taken into consideration when comparing the curve representing the unscreened grapefruit with that representing the screened grapefruit.

It was suggested that the screen cages protected the fruits on the screened trees from wind and that this was the cause for the fruits dropping sooner from the unscreened trees. Figure 93 gives a comparison

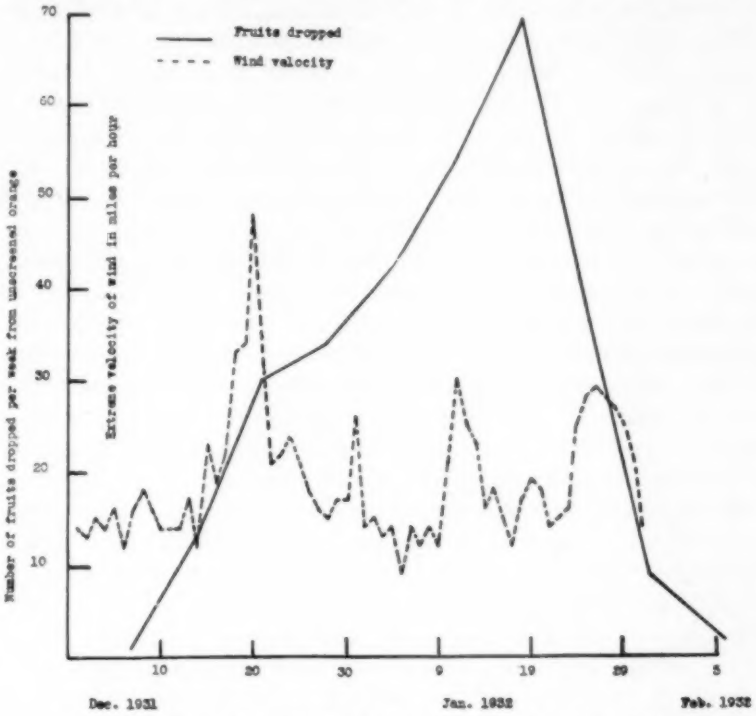

FIG. 93.—Time of fruit falling from orange tree and wind velocity.

between the time of dropping of fruits from the unscreened Valencia orange tree and the extreme wind velocities in miles per hour for the time during which all fruits dropped from the unscreened tree. It will be seen that, although the beginning of increased dropping of fruits at the weekly picking on December 21, 1931, apparently coincided with a high wind, later dropping of fruits was not due to high winds. The wind records were taken at the main Weather Bureau station in Honolulu, about 1½ miles away. The actual extreme velocities at the citrus grove should be lower than at the Weather Bureau station because of natural wind protection at the grove.

ATTEMPT TO ACCOUNT FOR DROPPING OF FRUITS.—In discussing the problem with Dr. M. B. Linford, pathologist of the Experiment Station of the Association of Hawaiian Pineapple Canners, the writer received many helpful suggestions. Later Doctor Linford made isolations of the organisms associated with fruit-fly punctures, and made some preliminary tests of their pathogenicity. Nine organisms were found associated with oviposition punctures. A fungus which Doctor Linford tentatively identified as *Penicillium digitatum* Sacc., the common green or olive-green mold of citrus fruits, appeared to be capable of causing fruits to drop soon after infection. A description of the disease caused by this fungus may be found in Citrus Diseases and Their Control, by Fawcett and Lee[2]. Because of the demand of other work for his time, Doctor Linford could not continue the experiments, but he offered many valuable suggestions for further work.

In an attempt to determine whether the olive-green mold organism would cause dropping of citrus fruits, two Valencia orange fruits and one Duncan grapefruit in the cages at the United States Experiment Station were inoculated with spores of the *Penicillium digitatum* organism. The fruits were first swabbed with 70 per cent alcohol and allowed to dry. Inoculations were made by puncturing the rind of the fruits ten times in two different areas with a needle that had been dipped in a suspension of the spores of the organism. Check punctures were made on other fruits with a sterile needle. Four days later all of the inoculated fruits were on the ground, with the characteristic soft rot developing at each circle of punctures. The check fruits were still on the tree, with no sign of disease on them. However, 3 days later one of the check oranges had dropped to the ground and the characteristic rot was developing at one circle of punctures. Upon close examination it was found that there were fruit fly larvae in the rotted area. By this time all the fruits had dropped from the check trees and it was therefore thought that such data would be very much worth while without jeopardizing the main experiment. The appearance of the disease in the check fruit with the larvae indicated that the female fruit fly, which had gained entrance to the cage, may have actually inoculated the fruit at the time of oviposition. On the other hand, the disease showing up in the check puncture with the fruit fly larvae may have been a coincidence, as the spores of the olive mold are usually very abundant wherever citrus fruits occur, and fruits readily become infected at any injured place in the rind.

Because of the character of the fungus (*P. digitatum*) and the habits of

[2]Fawcett, H. S., and Lee, H. A., Citrus Diseases and Their Control. New York, N. Y., 1926.

the female fruit fly, the carrying of the spores by the female is very probable. Fruit juice, which is attractive to the flies as food, often exudes from the soft rot. The fly often voids excrement while feeding and when doing this the female extends the ovipositor and drags it on the fruit or other object upon which she is resting. The ovipositor, therefore, would come in contact with the spores of the organism and would thus become contaminated, making inoculation of the fruit at the time of oviposition a very probable result.

When it was suspected that the female fruit fly might inoculate the fruits at the time of oviposition, tests were made to determine whether the olive-green mold disease could be produced by inserting in the rind of grapefruit or orange the ovipositor of a female collected in the citrus grove. In eight such tests only two fruits failed to become infected, while none of the check fruits produced the disease. The females used were collected in the citrus grove during the off season for fruits, consequently only a few flies were available. The same number of check and test fruits were used.

It is well known that one of the limiting factors in the infestation of citrus fruits by the Mediterranean fruit fly larvae is the resistance of the rag of the rind in preventing the larvae from reaching the pulp. Since the olive-green mold organism produces quite an area of soft rot within 3 days after inoculation, it follows that if the female should cause infection at the time of oviposition the development of the organism would soften the rag of the rind and in this way aid the larvae in gaining entrance to the pulp. The incubation of eggs takes 2 days at normal temperature. Several tests have been made in an attempt to determine whether this is the case and, although a higher percentage of infestation occurred in some tests, results have been inconsistent and a definite statement cannot be made at this time. It is felt that the experimental technic must be improved if reliable results are to be obtained. It is common knowledge that a minor injury to a fruit will cause premature ripening, especially if the injury occurs when the fruit is almost mature. This effect alone might account at least in part for premature dropping, but there has been no attempt to evaluate this effect in this discussion. It might be well to give some figures showing the number of oviposition punctures in samples of fruits as compared with the number of fruit fly pupae obtained from each sample. In 20 Pernambuco grapefruits in four consecutive weekly samples there were a total of 97 oviposition punctures and 47 pupae were obtained. In 10 Marsh grapefruits in two consecutive weekly samples there were 61 oviposition punctures and 6 pupae were recovered. In 30 Navel oranges in three consecutive weekly samples there were 172 oviposition punctures and 9 pupae were obtained.

SUMMARY

It has been found that citrus fruits drop to the ground and decay soon after ripening if the Mediterranean fruit fly is present in the grove.

Dropping of fruits has been correlated with oviposition punctures of the Mediterranean fruit fly.

Where citrus trees were screened to protect the fruits from fruit fly oviposition punctures, the fruits remained on the trees several months longer than on unscreened check trees.

A disease of citrus fruits, the olive-green mold, caused by the fungus *Penicillum digitatum* Sacc., has been isolated from oviposition punctures, and the ovipositors of female fruit flies collected in the citrus grove have been found to be contaminated with the spores of this organism.

Some data indicated that the female fruit fly may actually inoculate the fruit with spores of the olive-green mold at the time of oviposition.

It is believed that the dropping of fruits as a direct or indirect result of oviposition punctures by the Mediterranean fruit fly is the most important crop damage resulting from the presence of the Mediterranean fruit fly in citrus groves in Hawaii.

THE LETHAL EFFECT OF SEA WATER ON THE LARVAE OF THE MEDITERRANEAN FRUIT FLY (*CERATITIS CAPITATA* WIED.)

By R. H. MARLOWE and T. H. HONG,* *Bureau of Entomology, United States Department of Agriculture*

The Mediterranean fruit fly, a tropical insect of recognized economic importance, has spread from West Africa and Mediterranean Europe to other parts of the world by various agencies. Undoubtedly ships have aided in its distribution. Quantities of fruits and vegetables, some of which may contain fruit-fly maggots, may be taken on steamers at tropical ports; and as the boat approaches another port, particularly one where quarantine regulations are enforced, old or decayed fruit may be thrown overboard.

Should any of this containing live maggots reach the shore the insects may complete their development and, if conditions are favorable, become a menace to fruit production in a new area. This paper reports the results of investigations carried on at Honolulu, Hawaii, to determine the time infested fruits must remain in the sea to produce complete larval mortality, the time larvae may remain in floating or submerged

*Resigned from the Bureau of Entomology June 30, 1933.

fruit, and the lethal effect of sea water on larvae that have been forced to leave the fruit.

EFFECT OF SEA WATER ON LARVAE IN FLOATING FRUIT.—For the investigations on the lethal effect of sea water on larvae in their host fruits, a cage approximately 2 feet square and 5 feet high covered with half-inch mesh hardware cloth was placed in the sea at the Aquarium beach. The cage was held stationary by a concrete base and at such a depth that the fruits would be floating in the salt water at either low or high tide. Twenty different tests were made involving the use of 7 varieties of infested fruits. The number placed in the cage varied with the size of the fruit. Each test was repeated several times so that data would be available on a dependable number of larvae. Some of the fruits were removed from the sea at the end of each 24-hour interval and taken to the insectary, where they were placed in trays over sand. The sand was sifted daily for the recovery of maggots or pupae. Separate checks, equal in size to the samples removed at each of the 24-hour intervals, were retained in the insectary and the larval population at that time determined. This was used as a basis for estimating the population of the treated samples.

In these tests with infested fruits, seven common varieties of host fruits were floated in the sea for periods of 24 to 96 hours. A total of 3,248 fruits were used, that had a calculated larval content of 15,608 maggots. Of these fruits, from 60 to 65 per cent were in the sea water long enough for all the larvae to be destroyed. The variation in the time required for 100 per cent mortality as between the different host fruits, (Table 1), such as between the guava and sweet orange, is caused by factors other than the direct lethal effect of the sea water. The resistance offered to the diffusion of the salt solution by the skin, the texture, and the chemical composition of the fruit may cause a delay in the change of the environment immediately surrounding the insect.

A study of the data (Table 1) obtained from floating infested fruits in the sea shows that the time necessary to produce a 100 per cent mortality ranges from 24 to 72 hours, with guavas requiring the minimum. No living maggots were obtained from tangerines, calamondins, or sour oranges which had been floating 48 hours; whereas it was necessary to keep the mangoes, kamani nuts, and the sweet oranges in the sea 72 hours in order to obtain complete mortality. The salty taste acquired from the sea water became more distinct as the critical time for each variety was approached. Some of the survivors that were obtained from the various fruits pupated, and a high percentage of adults emerged from these pupae.

TABLE 1. THE LETHAL EFFECT OF SEA WATER ON LARVAE OF THE MEDITERRANEAN FRUIT FLY WHEN INFESTED HOST FRUITS ARE FLOATED IN THE SEA

Host	Infested fruit used	Estimated larvae* in fruit	Per cent mortality of larvae after floating for—			
			24 hours	48 hours	72 hours	96 hours
Wild guava (*Psidium guajava*)....	550	905	100	100	100	100
Tangerine (*Citrus nobilis*).....	300	858	93.0	100	100	100
Calamondins (*Citrus mitis*).....	600	1,593	96.6	100	100	100
Sour orange (*Citrus aurantium*)...	133	1,280	79.7	100	100	100
Mediterranean sweet orange (*Citrus sinensis*).....	165	412	71.7	94.3	100	100
Manila mango (*Mangifera indica*)..	300	3,390	97.1	99.6	100	100
Kamani nut (*Terminalia catappa*)..	1,200	7,170	94.4	99.3	100	100

*Based on the mean of two representative checks for each variety.

FORCED MIGRATION OF LARVAE FROM FLOATING FRUIT.—The investigations on the enforced migration of larvae as their environment absorbed sea water were conducted in the insectary. Fifty infested fruits were floated in each of four large vessels filled with salt water taken from the ocean and kept at temperatures approximating that of the ocean. One of these vessels was emptied at the end of each 24-hour interval, and the salt water examined for larvae and pupae. All of these found were then transferred to an environment favorable for development. Kamani nuts were the fruit selected for this work because of their abundance, high larval infestation, and resistance to penetration by salt water. The nuts used for the migration tests contained approximately 333 maggots per sample of 50 fruits.

Table 2 shows that, when infested material floats in sea water, some maggots leave the fruits as the salt water penetrates their environment. The number of larvae leaving each sample after 24 hours was 18, or 5.4 per cent; after 48 hours, 47, or 14.1 per cent; after 72 hours, 51, or 15.5 per cent; and after 96 hours, 53, or 15.9 per cent. Most of the escapes occurred between the 24- and 48-hour periods. Evidently during this time the larval environment changes to such an extent that maggots must migrate or succumb to the salt solution which is being absorbed by the fruit.

TABLE 2. LARVAE OF THE MEDITERRANEAN FRUIT FLY FOUND FLOATING IN THE SALT WATER AFTER REMOVAL OF KAMANI NUTS

Time nuts remained in the water	Active larvae			Inactive larvae			
	Pupated on removal	Adults emerged		Pupated on removal	Adults emerged		
						males	females
Hours	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
24.....	8	4	0	10	1	0	1
48.....	17	8	0	30	5	2	1
72.....	3	0	0	48	3	1	1
96.....	0	–	–	53	0	–	–

Observations on pupation and subsequent adult emergence of the larvae recovered from the salt water showed that a greater percentage of the active larvae pupated than of the inactive ones, but that adults emerged only from the pupae formed from larvae which were found inactive in the salt water. Besides the larvae that were recovered from the salt water, one to three dead pupae were found floating on the surface, which proves that larvae may pupate in salt water.

EFFECT ON FREE LARVAE OF SUBMERGENCE IN SEA WATER.—In order to procure data on the lethal effect of submerging third-instar larvae in sea water, experiments were conducted to determine the mortality, expressed as larval death, non-pupation, or adult non-emergence, after periods of 7, 12, 24, 36, 48, and 60 hours of submergence. One hundred individuals were used in the test for each period. They were divided into lots of 10, and each lot was placed in a glass vial (22 by 80 mm) containing 10 cc. of sea water. Four tests were made for each exposure period; thus 400 larvae were used for each time interval, or 2,400 larvae for the series. The sea water used for the work was obtained from the ocean and had a pH value of approximately 7.5. At the end of the submergence period the larvae were transferred to sand in petri dishes, where they were held for observations on mortality. The inability of the larvae to recover within 24 hours after removal from the water was the criterion used for death.

An analysis of the data in Table 3 shows that 387 larvae out of 400 survived 6 hours' submergence and pupated. A total of 252 adults and

TABLE 3. EFFECT OF SUBMERGENCE IN SEA WATER ON LARVAE OF THE MEDITERRANEAN FRUIT FLY

Hours submerged	Number of larvae	Number revived	Number pupated	Adults emerged	Per cent non-emergence from pupae	Parasites*		
						(1)	(2)	(3)
6	400	387	387	252	34.9	4	4	20
12	400	382	382	192	49.7	17	15	0
24	400	247	224	129	42.4	3	3	0
36	400	66	42	19	54.8	1	0	0
48	400	25	9	3	66.7	0	0	0
60	400	0	—	—	—	—	—	—

*(1) *Opius humilis*. (2) *Diachasma tryoni*. (3) *Tetrastichus giffardianus*.

28 parasites emerged, which gave a pupal mortality of 34.9 per cent. Twelve hours of submergence decreased the number of larvae reviving and pupating to 382. However, the pupal mortality showed a considerable increase over that of the 6-hour submergence test. A total of 247 larvae survived 24 hours in the water, whereas only 66 and 25 recovered after being submerged 36 and 48 hours, respectively. Sixty hours in salt

water proved to be sufficient to kill all individuals. The pupal mortality increased from 34.9 per cent at 6 hours' submergence to 66.7 per cent for 48 hours' submergence, showing an almost uniform relation between larval submergence time and adult non-emergence. The part played by parasites in the percentage of pupal mortality is negligible, since check tests gave an adult non-emergence of 5 per cent. The parasites were more susceptible to sea water than the fruit fly larvae, as they did not survive over 36 hours submergence of their host.

If the larvae have not been in the sea long enough to be killed (from 48 to 60 hours) there is a possibility of their development to adults. Third-instar larvae will pupate in sea water provided they have reached maturity and are able to hold their posterior spiracles at the surface and in direct contact with the air. If they are not able to so hold themselves they will sink. Pupae formed in salt water and kept in it for 24 hours or longer will not produce adults.

Assuming that a larva may survive a 54-hour period in the sea and pupate and remain another 18 hours in the water as a pupa and still develop to an adult, it would appear that any infested material that is thrown into the sea and is beached within 72 hours may serve as a potential source of fruit-fly introduction.

Summary

Salt water will penetrate throughout an infested fruit when it is placed in the sea, and the time required depends upon the composition and texture of the fruit.

The fruit-fly larvae are unable to adjust themselves to the environmental change which occurs as the fruit absorbs salt water, and the maggots either succumb or leave the fruit in order to find a more favorable habitat.

When infested fruits that had not been in the sea for an adequate time to insure complete mortality were removed to a favorable place, the larvae emerged and completed their normal development, indicating that it is possible for infested fruits, when thrown into the sea near land, to be washed ashore and serve as a source of fruit-fly introduction.

Maggots, upon leaving their fruit environment, attempt to hold their posterior spiracles at the surface of the water and may pupate in this position. Pupae thus formed succumb after 24 hours of floating in the salt water.

Larvae which do not pupate in salt water become inactive and die, the submergence time for complete larval mortality ranging from 48 to 60 hours.

The disposal of infested fruits or waste products by dumping them into the sea where they may float ashore within 72 hours serves as a potential source of infestation.

FUMIGATION FOR EUROPEAN EARWIG (*FORFICUI A AURICULARIA* LINN.) IN BALLED NURSERY STOCK

By JOHN B. STEINWEDEN, *Deputy Agricultural Commissioner, San Francisco, California*

The infestation of ornamental nursery stock by the European earwig (*Forficula auricularia* Linn.) presents a problem in the movement of nursery stock from infested to non-infested areas. The earwigs are found under the burlap coverings of the balls, or hidden in cracks and crevices in the soil, so that they are easily transported by balled stock. Nursery stock from Washington and Oregon, especially balled evergreens, is occasionally found infested on arrival in California and its rejection by quarantine officials has caused considerable loss at times to consignor and consignee.

Two carloads of balled evergreens from Oregon were vacuum fumigated with HCN at San Francisco in November, 1931, with only a partial mortality of earwigs, using 25 cc. of HCN per 100 cubic feet for 1 hour at a vacuum of 26 inches. In September, 1933, a carload of balled ornamental nursery stock was severely burned in attempting to obtain 100% mortality with vacuum fumigation. These results led to further experimentation in order to arrive at definite recommendations for future treatment of infested plants.

EXPERIMENTAL METHODS.—Adult female and male specimens of European earwigs (*Forficula auricularia* Linn.) were used. These were obtained from infested nursery stock which was treated, and from one local infested area. The small number of specimens used was due to the lack of material available during the fall and winter months when most of the experimental work was done.

The vacuum fumigation was carried on with liquid HCN in the 900 cubic feet and 1700 cubic feet retorts of the California Cotton Mills at San Francisco, and in a small 12.5 cubic feet tank belonging to the U. S. Plant Quarantine Service at San Francisco. The calcium cyanide used was Cyanogas, A-dust, containing between 40% and 50% calcium cyanide. The para-dichlorobenzene and naphthalene flakes used were the unadulterated commercial products.

TABLE 1. THE EFFECT OF VACUUM HCN FUMIGATION ON EUROPEAN EARWIG (*Forficula auricularia*) IN BALLED NURSERY STOCK

Dosage	Time	Vacuum	Temp.	No. earwig	Per cent killed	Remarks
20 cc. per 100 cu. feet	1 hour	27″ not held	63° F	3	100	Vial of earwigs loose in fumigation tank.
20 cc. per 100 cu. feet.	1 hour	26″ not held	64° F	4	100	Vial of earwigs loose in fumigation tank.
21 cc. per 100 cu. feet.	1 hour	26″ not held	68° F	3	66.6	Vial placed under burlap of a ball.
21 cc. per 100 cu. feet.	1 hour	26″ not held	68° F	3	0	Vial of earwigs placed 3″ in box of soil.
21 cc. per 100 cu. feet.	1 hour	26″ not held	68° F	3	0	Vial of earwigs covered with soil.
21 cc. per 100 cu. feet.	1 hour	26″ not held	64° F	3	100	Vial of earwigs loose in fumigation tank.
21 cc. per 100 cu. feet.	1 hour	26″ not held	60° F	3	100	Vial of earwigs loose in fumigation tank.
21 cc. per 100 cu. feet.	1 hour 5 min.	26″ not held	64° F	3	100	Vial of earwigs loose in fumigation tank.
21 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	73° F	3	100	Vials of earwigs loose in fumigation tank.
21 cc. per 100 cu. feet.	1½ hour	26″ (held at 15″)	57° F	3	100	Vial of earwigs loose in fumigation tank.
21 cc. per 100 cu. feet.	2 hour 45 min.	26″ (held at 15″)	62° F	2	0	Vial of earwigs buried in 3″ of soil during fumigation.
21 cc. per 100 cu. feet.	2 hour 45 min.	26″ (held at 15″)	62° F	3	0	Vial of earwigs buried in soil left buried 21 hours after fumigation.
23 cc. per 100 cu. feet.	1 hour	26″ not held	68° F	3	100	Vial of earwigs buried in 3″ of soil, left buried 43 hours after fumigation.
25 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	64–66° F	3	100	Vial with earwigs placed under burlap of a ball.
25 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	64–66° F	3	100	Vial with earwigs placed under burlap of a ball.
25 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	64–66° F	3	100	Vial with earwigs loose in fumigation tank.
25 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	64–66° F	3	0	Vial with earwigs covered with loose soil during fumigation.
25 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	64–66° F	3	66.6	Vial with earwigs covered with loose soil during fumigation.
25 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	64–66° F	3	0	Vial with earwigs buried in 3″ of loose soil during fumigation.
28 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	73° F	2	100	Vial with earwigs buried in 3″ of soil, left buried 22 hours after fumigation.
28 cc. per 100 cu. feet.	1 hour	26″ (held at 15″)	73° F	3	100	Vial of earwigs loose in fumigation tank during fumigation.
None	1½ hours	27″ (held)	60° F	3	0	Vial of earwigs loose in tank.
⅔ ounce NACN per 100 cu. ft.	35 min.	None	75° F	3	66.6	Vial of earwigs placed inside of a box of oranges.

Individual plants were fumigated with calcium cyanide which was poured around and on top of the ball inside of the burlap wrapping. The ball was then tied up tightly in a large piece of rubberized sheeting so that the foliage was not exposed to the gas. Para-dichlorobenzene and naphthalene were used in the same manner except that the balls were wrapped in a canvas instead of rubberized sheeting.

PROCEDURE.—The earwigs to be fumigated were placed in small glass vials 52 mm. x 16 mm. which were covered at the mouth with three or four layers of gauze fastened with a rubber band. The test vials were then put in the tank loose, buried in soil, buried in the balls of nursery stock, or placed under the burlap wraps of the balls. Except when the vials were left in soil for a day or two after fumigation, examination of the earwigs was made immediately after the fumigation, and daily for several days. The treated earwigs were kept in a warm room in the same vials in which they were fumigated. Death did not occur in many cases until three or four days after treatment.

DISCUSSION OF EXPERIMENTS—EFFECTIVE TREATMENTS.—It will be observed in the preceding table that earwigs loose in the fumigation tank and not covered by burlap wrappings of the balls or not buried in soil were killed by 20 cc. of HCN per 100 cubic feet for 1 hour at a vacuum of 26 inches. In order to obtain 100% mortality of earwigs under burlap coverings, it was necessary to increase the dosage of HCN to 25 cc. for the same time of exposure, and same vacuum. 100% mortality to earwigs covered with soil or buried in 3 inches of soil was questionable even at higher dosages, such as 28 cc. for 1 hour or 21 cc. for as long as 2 hours and 45 minutes. This is probably due to absorption of the gas by the soil. No difference in mortality was noted when the vacuum was held and when it was broken down after the gas was drawn into the tank. The temperature should be 60 degrees F. or above.

EFFECT ON PLANTS.—Balled evergreen stock such as *Chamaecyparis obtusa*, *Retinospora plumosa*, English Holly, Daphne, hemlock, *Cedrus atlantica*, *Thuya occidentalis*, and *Hemlock heterophylla* was injured to some extent at any dosage over 15 cc. of HCN for 1 hour. Other stock such as many Rhododendron species, *Picea pungens* and *P. engelmanni*, *Retinospora filifera*, Blue Lawson Cypress, some of the Junipers and Abies were able to withstand 20 cc. of HCN.

Practical interpretation of this information shows that 100% mortality of earwigs cannot be obtained without serious injury to evergreen plants because many of the earwigs will be hidden in crevices of the balls or even buried 3 or 4 inches in the soil, which necessitates a high dosage of HCN or a long exposure.

TABLE 2. THE EFFECT OF ATMOSPHERIC FUMIGATION OF INDIVIDUAL BALLED PLANTS WITH CALCIUM CYANIDE FOR EUROPEAN EARWIG (*Forficula auricularia*)

Dosage	Time	Temp.	No. earwigs	Per cent killed	Remarks
¼ oz. per plant (boxwood) (1 teaspoonful)	24 hours	64° F max.	3	100	Vial of earwigs partially covered with overhanging roots and soil, near top of clay ball.
¼ oz. per plant (boxwood) (1 teaspoonful)	24 hours	64° F max.	3	100	Vial of earwigs buried approximately 1½″ inside of clay ball, half way down side.
½ oz. per plant (Erica) (2 teaspoonsful)	24 hours	64° F max.	4	100	Vial of earwigs in crown of plant on outside of ball.
½ oz. per plant (Erica)	24 hours	64° F max.	4	100	Vial of earwigs placed under burlap wrapping of ball halfway down side.
½ oz. per plant (Erica)	24 hours	64° F max.	2	100	Vial of earwigs buried in top of ball, 1″ below surface.
¾ oz. per plant (Erica) (3 teaspoonsful)	24 hours	66° F max.	6	100	Vial of earwigs buried in 1″ of soil half way down side of sandy loam ball.
¾ oz. per plant (Erica)	24 hours	66° F max.	5	100	Vial of earwigs covered with 1½″ of soil in a sandy loam ball.
¼ oz. per plant (Thuya) (1 teaspoonful)	48 hours	62° F max.	4	100?	4 dead earwigs found in loose soil of clay ball.
½ oz. per plant (Erica)	24 hours	64° F	16	68.75	Vial buried in 1½″ of soil, halfway down side of ball.
¾ oz. per plant (Erica)	24 hours	60–65° F	18	100	Vial buried in side of ball in 1½″ of soil.
1 oz. per plant (Erica)	24 hours	60–65° F	7	100	Vial buried covered with 2″ of soil inside of ball.

Note: The plants used were a small boxwood 33″ tall with a ball 10″ in diameter and an Erica 34″ tall with a ball 13″ in diameter.

TABLE 3. THE EFFECT OF FUMIGATION OF BALLED PLANTS WITH PARA-DICHLOROBENZENE FOR EUROPEAN EARWIG (*Forficula auricularia*)

Dosage	Time	Temp.	No. earwigs	Per cent killed	Remarks
1 oz. per plant....	48 hours	64° F max.	4	100	Vial of earwigs placed inside of burlap near bottom of ball.
1 oz. per plant.....	48 hours	64° F max.	4	100	Vial of earwigs buried 1″ in soil halfway down side of ball.
1 oz. per plant....	48 hours	70° F max.	5	100	Vial of earwigs buried 1″ in soil halfway down side of ball.
⅗ oz. per plant...	48 hours	63–65° F	9	11.11	Vial covered with mass of roots.
⅗ oz.....	48 hours	63–65° F	7	0	Vial covered with 1½″ of soil.
1 oz. per plant....	48 hours	62° F max.	10	0	Vial buried in 2″ in soil.
Naphthalene Flakes					
1 oz. per plant....	48 hours	64° F max.	2	0	Vial of earwigs covered with 1″ of soil half way down side of ball.
1 oz. per plant....	96 hours	64–65° F	20	100	Vial loose inside of burlap.
1 oz. per plant....	96 hours	64–65° F	12	0	Vial buried in soil of ball.

Note: Small veronica plants 18″ tall with balls 7″ in diameter and boxwoods approximately 33″ tall with 10″ balls were used in these experiments.

DISCUSSION OF EXPERIMENTS.—It is apparent from the above table that ¾ of an ounce of calcium cyanide for a small plant such as a 3 foot Erica for a fumigation time of 24 hours was effective against loose earwigs and those buried in the soil.

The temperature should be 60 degrees F. or above during most of the time of treatment. There was no apparent injury to the plants as the foliage was dry and not directly exposed to the gas. The only objection to this method of treatment is the labor involved in wrapping and unwrapping the individual plants and some annoyance incurred in applying the calcium cyanide.

DISCUSSION OF EXPERIMENTS.—The above results indicate that 1 ounce of para-dichlorobenzene applied to the balls of small plants, such as the Veronicas or boxwoods here used, for 48 hours was effective against earwigs loose under the wrappings of balls, but was not effective against those earwigs buried in cracks and crevices of the soil.

Naphthalene flakes used at the rate of 1 oz. per each small plant for 48 hours to 96 hours was not effective against earwigs in the balls.

SUMMARY AND CONCLUSIONS.—Vacuum fumigation with HCN of large quantities of balled evergreen nursery stock infested with European earwig has proved ineffective due to the fact that a dosage which the plants would safely withstand was not strong enough to kill earwigs within the earthen balls.

Individual plants can be fumigated effectively and safely with calcium cyanide by dusting the fumigant around the ball inside of the burlap covering and then wrapping the ball tightly in a rubber tarpaulin. The amount of calcium cyanide varies with the size of the plant, but three-fourths of an ounce is recommended for a medium sized plant such as a 3 foot Erica, for a fumigation time of 24 hours.

Para-dichlorobenzene used in the same manner as calcium cyanide at the rate of 1 ounce for a small plant for a fumigation time of 48 hours is effective only against earwigs under the burlap coverings of the balls and not against those buried in the soil.

Naphthalene flakes used at the rate of 1 oz. per each small plant for 48 hours to 96 hours was not effective against earwigs in the balls.

THE BUFFERING POWER OF THE CONTENTS OF THE VENTRICULUS OF THE HONEYBEE AND ITS EFFECT UPON THE TOXICITY OF ARSENIC[1]

By W. M. Hoskins and A. S. Harrison

The effect of the hydrogen ion concentration of solutions containing arsenic upon their toxicity to insects has received attention recently. In an article from this laboratory (Hoskins, 1932) it was shown that the toxic action to mosquito pupae of dilute solutions of arsenious acid (pH 5) is about four and one-half times as rapid as that of solutions containing the same concentrations of sodium arsenite (pH 11). Pearson and Richardson (1933) stated that they expected similar results with houseflies but actually found no appreciable difference in the toxicity. They attributed this to a buffering effect within the digestive tract of the flies. Unpublished results from this laboratory show that there is less difference in the toxicity to mosquito larvae of acid and basic solutions of trivalent arsenic than was found with mosquito pupae and this also is considered as probably due to a buffering effect within the digestive tract of the larvae.

There appears to be no data in the literature by which the toxicity of an insecticide and the buffering power of the contents of the digestive tract of an insect may be correlated. Swingle (1931) gave data from which this buffer value can be calculated for the larva of the Japanese beetle, but his work did not include anything on toxicity. It appeared worthwhile to undertake such a study. Arsenic was selected as the toxic substance and the honeybee as the insect since bees are readily obtainable throughout the year and can be kept on a simple and standard diet if desired. Field bees of an Italian colony were used in all cases.

Methods and Results of Toxicity Experiments.—It was decided to give trivalent arsenic at several dosages, between approximately 0.15γ and 4.0γ (micrograms), calculated as elementary arsenic per bee. A few preliminary experiments showed that a hungry bee will readily imbibe 0.025 cc. of sugar solution. Hence the arsenic solutions were prepared so that the amounts mentioned above were contained in 0.025 cc. These were all made by dilution of a stronger solution of sodium meta arsenite in distilled water and contained in 0.025 cc. of solution, 0.152, 0.294, 0.556, 1.00, 1.50, 1.66, 2.50 and 4.00γ arsenic, respectively, according to analysis by the Gutzeit method. Each solution was also approximately half saturated with ordinary cane sugar. No other substances were in-

[1]Contribution from the laboratory of insect physiology and toxicology, Division of Entomology and Parasitology, University of California.

cluded in these solutions, which all had a pH value between 7.4 and 8.0 and possessed only the very low buffering power of the arsenic compound present.

The bees were caught as they left the hive in a wire feeding cage about 3 by 4 by 5 inches of the type described by Bertholf (1933), and were kept without food for two to four hours which is sufficient time to make them hungry but not weak from starvation. The feeding method of Price (1920) was then used with one modification. A capillary pipette was calibrated to deliver 0.025 cc. of liquid, which was placed on a waxed slide. A hungry bee was put within an inverted glass funnel standing on a table top and the slide with the drop of arsenical liquid was slipped beneath the funnel. A majority of the bees came to the drop of liquid and began eating without previously disturbing it. In only a few cases did feeding cease before the liquid was entirely consumed. In such instances the bees were discarded. This method has an advantage over that of Price in that weighings are avoided and changes in weight due to evaporation from the drop of liquid do not lead to error. Another method of giving the poison liquids was based on the observation that if bees are liberated on a window sill their positive phototropism is strong enough to keep them on the window, where they may be offered liquids from the tip of a capillary pipette. As soon as each bee had finished feeding it was replaced in a wire feeding cage. Tests were run with lots of ten bees kept together in one cage and fed concentrated sugar solution. The wire bottom cages were placed upon open Petri dishes filled nearly to the rim with sugar solution and cotton batting. Bees standing or lying, as sick ones often did, on the wire bottom of a cage could easily reach the sugar solution without becoming soaked by the sticky liquid as happens with overhead feeding devices. Since bees die within a few hours if unable to obtain food it is important to make adequate arrangements for feeding them. Approximately eight hundred bees were used in the tests of this series. Control cages of bees treated in the same way except for feeding with arsenic showed practically no mortality during the lengths of time concerned. No attempt was made to control the temperature but it was always between 18 and 25° C.

The toxicity of the various arsenic solutions was evaluated in terms of the length of time after feeding required to kill fifty per cent of the bees. The usual difficulty in determining when an insect is dead applies to this type of experiment. After an interval of a few minutes to many hours, depending upon the amount of arsenic consumed, the bees became uneasy, began to stagger about and eventually could no longer stand. A bee was counted as dead when no twitching or other movement was ob-

served upon frequent and careful inspection over a period of a half hour or more. It was found that gentle pressure upon the abdomen brought a response from the still-living bees more certainly than did any other test tried.

For each dosage of arsenic a graph was made showing the number of dead bees in each separate test plotted against the time after feeding when each death occurred. A smooth curve was drawn through the points by eye. With all concentrations except the lowest and highest the familiar "S" shaped curves resulted. From these graphs the time required for each amount of arsenic to kill fifty per cent of the bees was read off. These are shown in Figure 94, which also includes the data for individual bees in Price's article (1920) on the interval after which death followed the ingestion of various amounts of soluble trivalent (?) arsenic. Since the time for fifty per cent mortality would probably be about half that for individual deaths, the agreement is good except at the lower concentrations. Price kept his bees overnight without food. In the present work this was found to seriously weaken most of the bees. Such weakened bees doubtless would succumb to arsenic more readily than healthy ones and the discrepancy may be expected to be more marked with smaller amounts of poison.

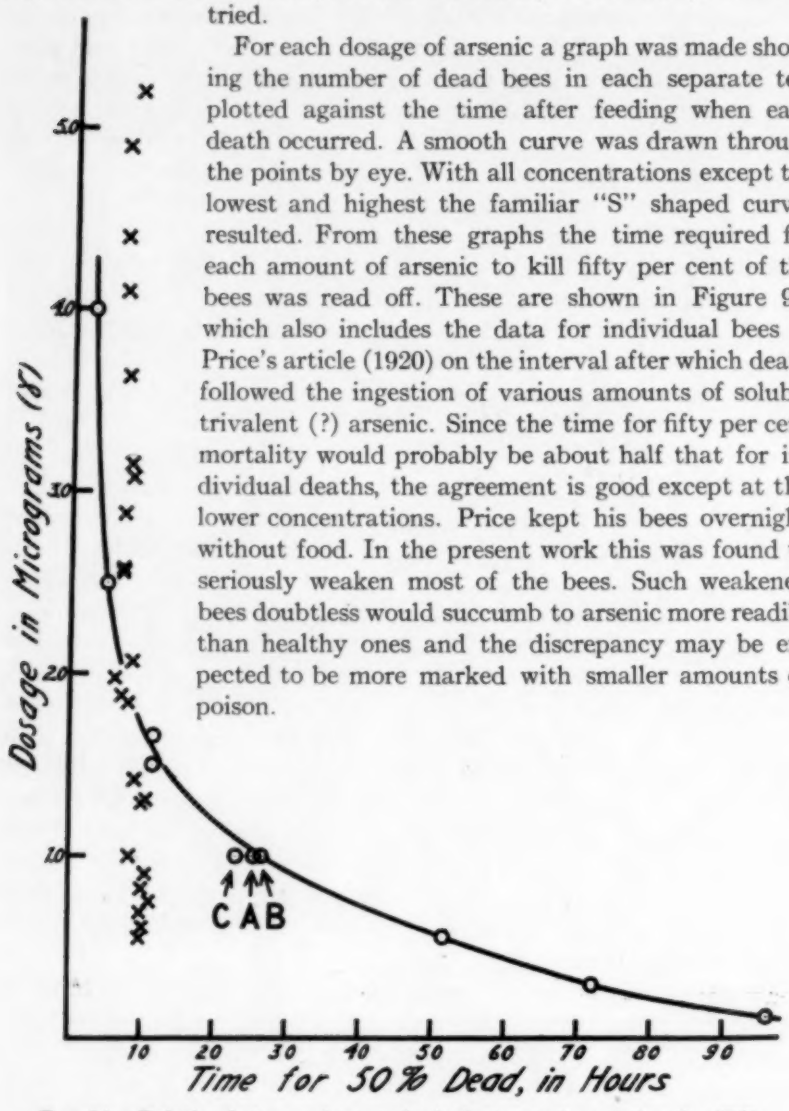

FIG. 94.—Relation between dosage of trivalent arsenic and time for 50% mortality. 0 = results of present work. x = results of Price (1920) for time of individual deaths.

Figure 94 shows that whereas the survival time is roughly inversely proportional to the dose of arsenic for small amounts, a point is reached at about two micrograms beyond which but little shortening of the period results from larger doses. Plotting these data as the logarithm of amount of arsenic versus logarithm of time for fifty per cent mortality (O'Kane, et al, 1930) does not give a straight line. This may indicate possibly that the mode of toxic action of arsenic varies with different amounts consumed. No special attempt was made to determine a minimum lethal dose but the curve of Figure 94 indicates that for solutions of sodium meta-arsenite it lies between 0.1 and 0.2 micrograms of elemental arsenic for bees treated as described above.

To test the effect of using arsenite solutions of different pH, two solutions were prepared containing 1.0 microgram of arsenic per 0.025 cc. and cane sugar as before. One was brought to pH 5 by cautious addition of dilute hydrochloric acid and the other to pH 9 by adding sodium hydroxide solution. La Motte indicators and standard pH tubes were used for testing these preparations. The solutions were given to bees exactly as before, no repellent effect being noticed. The results are also shown in Figure 94 at points marked A and C. It will be noted that for the three solutions, each containing 1.0 microgram of arsenic in 0.025 cc. and being respectively at pH 5, pH 8 and pH 9, the times required for fifty per cent mortality are 25.5, 26.5 and 23.0 hours. This variation is undoubtedly within the experimental error involved in dealing with such small volumes of solution and such susceptible insects. This conclusion is particularly reasonable since no trend with pH is shown.

It is not possible to contrast these results directly with those obtained using mosquito pupae since these dilute solutions (1γ As per 0.025 cc. is about 0.0005M) are not appreciably toxic to the latter insect. But unpublished data from this laboratory show that when mosquito pupae are placed in 0.02 M arsenite solutions at pH 5, pH 8 and pH 9 the exposures for fifty per cent mortality are respectively eighty, one hundred and ten and one hundred and forty minutes.

Since the primary object of the present work was a study of the buffering power of the honeybee's digestive fluids, attention was turned to this problem without further tests of the toxicity of other amounts of arsenic.

Normal pH of contents of Digestive Tract and of Body Fluid of the Honeybee.—The close similarity in toxicity of acid and basic solutions of trivalent arsenic indicated that after ingestion the arsenic was brought to practically the same condition in both cases. This is indirect evidence of a buffering effect of the contents of the absorbing

portion of the digestive tract. Before beginning an investigation of this buffer power, a short study was made of the normal pH of different portions of the digestive tract and of the effect of ingesting acid and basic solutions. The bees were caught as described before, and either used at once, or fed on sugar solution until needed. To aid in handling them each bee was put into ether vapor until quiet, and then placed upon a soft beeswax-paraffin surface, which held the body firmly enough for dissection without pinning. The digestive tract was then dissected out without loss of its contents, rinsed in three portions of freshly boiled and cooled distilled water and blotted dry with filter paper. The tip of a fine-pointed capillary tube was then inserted into the cavity of the organ being studied, and a portion of liquid drawn out. Care was taken to exclude solid material but some was often taken into the tube. The liquid was immediately mixed with a small drop of an indicator solution on a spot plate and the color compared with standard pH solutions. Another method of using the indicator method was also employed. A small amount of indicator solution was drawn into the capillary tube, its tip inserted into the digestive organ and some of the contents drawn into the tube. The characteristic color developed in the region where mixing occurred. Both these procedures suffered from the natural color of the contents of most parts of the digestive tract. However, closely agreeing results were obtained in many tests with the honey stomach and ventriculus.

To check the accuracy of the colorimetric determination of pH, an apparatus for electrometric testing with a quinhydrone electrode was devised. Figure 95 shows the essential parts. A shallow depression, three millimeters across, was made in the center of a piece of 28 gauge platinum foil, A, about one centimeter square. This was fastened to a short piece of platinum wire, B. The square piece of foil was then set upon four glass points built up from a portion of a flattened soda glass tube, C. The wire was sealed through the wall of the tube beyond the flattened portion. By carefully heating the platinum foil in the region of each glass point, these were melted enough to make a firm union with the foil. The whole contrivance could be washed and dried easily. Mercury, D, was put into the tube to make contact with the platinum wire and another wire (copper) led from the mercury to a type K potentiometer. The tube bearing the platinum foil was mounted in the lens holder of an old microscope stand so that it could be raised and lowered easily and accurately. The rest of the apparatus consisted of a capillary tube, E, filled with agar saturated with potassium chloride, and surrounded at its lower end by a bell-shaped piece of glass, F, which was clamped to a

ringstand. The tube, E, was connected through a short rubber tube, G, with a 1N calomel electrode, which was connected to the potentiometer. The bottom ring of F was ground off smoothly and coated with vaseline so that when the foil, A, was raised, a tight joint was made. The opening through which tube E entered F was also treated with vaseline so that the space within F could be completely shut off from the surrounding atmosphere. As needed the tip of tube E was broken off to give contact with fresh potassium chloride-agar gel.

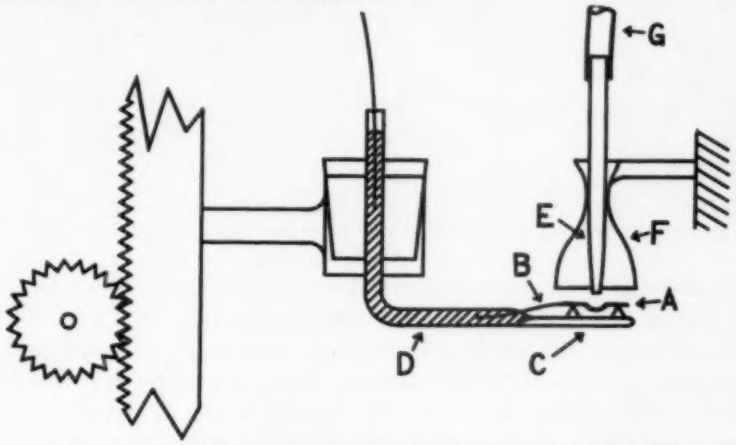

FIG. 95.—Sketch of apparatus used for electrometric determination of pH.

In using this apparatus a few grains of quinhydrone were placed in the depression in the foil. Fluid was taken from a portion of the digestive tract as described before and put into the depression, where it was quickly mixed with the quinhydrone. Upon raising the platinum foil the tip of tube E made contact with the liquid and the circuit was complete. Equilibrium was usually reached within a half minute and remained quite steady thereafter. All potentiometric determinations were made in an air bath kept at 25.0 ± .1° C. except in a few cases for which correction was made. Care was taken to keep exposure to the air as short as possible, though in the light of the buffering power found later, this was of no importance. The electrode was checked at intervals with buffer solutions to make sure that it was functioning properly.

Table 1 is a summary of what may be called the normal pH value of the larger organs of the digestive tract of the honeybee. No difference was found between bees taken directly from the hive and those kept for a few hours on sugar solution. A protracted diet of sugar was not tried.

Most of the determinations were made on the contents of the ventriculus, and the earlier ones were directed toward comparing the results by the colorimetric and electrometric methods. The values given are the average of at least six concordant results, and it will be seen that they are all that can be expected with a liquid as strongly colored as the ventricular contents. Tests on other parts of the digestive tract were amply checked, but were regarded as not of primary interest in this investigation.

TABLE 1. NORMAL pH VALUES OF VARIOUS PARTS OF THE DIGESTIVE TRACT AND OF THE BODY FLUID OF THE HONEYBEE

Organ	Colorimetric	Electrometric
Honey stomach	6.3	——
Ventriculus	6.3	6.25
Hind gut (small intestine)	4.6–4.8*	——
Rectum	——	5.45
Excrement	5.4	——
Body fluid (blood)	6.7	6.70

*The very small volumes of liquid obtainable and the danger of contamination from the ventriculus and rectum make this value much less certain than the others.

Colorimetric determinations were made with solutions of both brom thymol blue and chlorphenol red. To make sure that etherizing the bees had no effect, a number were decapitated and tested with identical results. Body fluid, uncontaminated by liquids from the digestive tract is most easily obtained by carefully snipping off the abdomen and head of a bee and then gently squeezing the back part of the thorax. A drop of the clear, pale yellow liquid will appear at the anterior end. To insure that fluid from the esophagus was not having an effect upon the pH, samples of blood were obtained by pulling off legs from several individuals. The results were identical with the previous ones.

TABLE 2. pH OF THE CONTENTS OF THE HONEY STOMACH AND VENTRICULUS AFTER BEES WERE FED 0.025 CC. OF A BUFFERED ARSENIC SOLUTION CONTAINING 0.556 MICROGRAMS OF ARSENIC

Time	0.2 M Phosphate buffer at pH 5		0.2 M Phosphate buffer at pH 9	
	Honey stomach	Ventriculus	Honey stomach	Ventriculus
Immediately	5.8	6.2	6.9	6.2
15 minutes	5.9	6.2	6.8	6.2
30 "	5.9	6.2	6.8	6.3
45 "	6.0	6.2	6.7	6.3
60 "	6.0	6.2	6.6	6.2
75 "	empty	6.2	empty	6.2

As a preliminary experiment on buffering power two large groups of bees were taken, one of which was fed 0.025 cc. each of a solution containing 0.556 micrograms of arsenic and 0.2 M phosphate buffer at pH 9. The other group was fed similarly but with a solution buffered at pH 5. The pH of the contents of the honey stomach and of the ventriculus was

determined at intervals after feeding, the colorimetric method being used. Each result is the average of six closely concordant determinations.

The above results show that under the experimental conditions the pH of the honey stomach varied considerably whereas that of the ventriculus remained practically unchanged. Since the volume of liquid within the organs before the buffered solutions were drunk is not known, no quantitative deductions can be drawn. An attempt was made to exhaust the natural buffering power of the secretions of the ventriculus by feeding bees on a buffered sugar solution containing no arsenic. This led to marked diarrhea and after the first day the liquid was accepted only in very small quantities. Within three days the bees were dead and no results were obtained on the buffering effect.

THE BUFFERING POWER OF THE CONTENTS OF THE VENTRICULUS.—The determination of the buffering power of a solution depends upon finding the resultant hydrogen ion concentration after various amounts of acid or base are added to a definite volume of the solution. In the present case a few preliminary tests showed that the region of main buffer action was on the acid side. Accordingly, a series of solutions of hydrochloric acid was made covering the range of 0.01N to 0.2N at intervals of 0.01N and a similar series with sodium hydroxide from 0.01N to 0.04N was prepared. The bees were treated as before and some of the liquid in the ventriculus was drawn up into a long, narrow bore capillary tube. The contents were expelled onto a spot plate or the platinum foil, depending upon the method used for determining the pH. The capillary tube was then washed out in distilled water and an equal volume of one of the acid or basic solutions added and the mixture stirred. In the colorimetric method a small drop of indicator solution was added and the color compared with standard buffer solutions. An attempt to mix all three liquids within the capillary tube was unsuccessful in most instances, and was abandoned. When the electrometric method was employed a few grains of quinhydrone were placed in the depression of the platinum foil, and the E.M.F. determined as described in the section on normal pH values. In practically all instances, except with the highest concentration of acid, the color or the E. M. F. became constant almost at once. The indicator brom cresol green did not behave normally in the presence of ventricular fluid, for it became a purple color on the alkaline side, instead of blue-green. Above pH 7.5 the quinhydrone electrode did not give reproducible results. The method described above for using a variable volume of ventricular fluid instead of a constant volume was necessary, because the amount obtainable varied considerably and it was

desirable from the standpoint of accuracy to use as large a volume as possible.

Figure 96a contains the data from these tests. Each point is the average of from three to ten separate determinations, the ventricular contents of a different bee being used in each case. No systematic difference was shown between the colorimetric and electrometric methods and the latter was used for most of the determinations. No difference was noted between bees on natural diet and those on sugar diet for a few hours, so no distinction is made in the figure.

The most useful measure of buffering power is the ratio of equivalents of acid or base added to the resultant change in pH. If this ratio is approximately constant over the range considered, the "buffer value" β, is defined as equal to $\frac{\Delta A}{\Delta pH}$ or $\frac{\Delta B}{\Delta pH}$ in which ΔA and ΔB signify equivalents of strong acid or base added. If the ratio is not constant over a range the differential quotient must be used and $\beta = \frac{dA}{dpH}$ or $\beta = \frac{dB}{dpH}$. To evaluate this from experimental data it is necessary to draw a smooth curve through points such as those of Figure 96, and construct the tangent at any desired point.

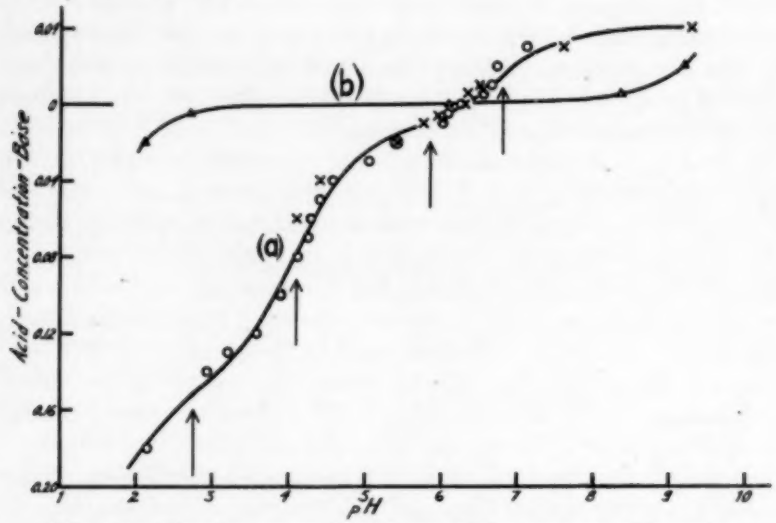

FIG. 96.—Titration curves for (a) ventricular contents of honeybee, (b) sugar solution. x = colorimetric determinations, 0 = electrometric determinations.

A buffer system in the simplest case consists of a weak acid or base and its salt formed with a strong base, or acid. An example is the acetic acid-sodium acetate system. When this combination is treated with an acid or a base, the result is a change in the relative amounts of acetic acid and its salt and a change in the pH of the solution. The curve showing the relation between pH and added acid or base is a titration curve. The slope at each point measures the buffering power, β, which is the resistance of the solution to change in pH. This buffering power usually varies from point to point and if but one buffer system is present, it can be shown that maximum slope, and therefore maximum buffering power, occurs when the pH equals pK_a^1, which is related to the dissociation constant of the acid of the buffer combination (van Slyke, 1922). If K_a is the acid dissociation constant,

$$K_a^1 = \frac{K_a}{\gamma_s} \quad \text{.....Eq. 1}$$

in which γ_s is the degree of dissociation of the buffer salt.

$$\text{Then } pK_a^1 = -\log K_a^1 \quad \text{.....Eq. 2}$$

which is similar to the convention, $pH = -\log (H^+)$. Also at this point of maximum buffering power the buffer system consists of equal proportions of acid and its salt. The total concentration of buffer (acid plus salt) is given by the equation.

$$C = \frac{\beta}{0.575} \quad \text{.....Eq. 3}$$

If the buffer system consists of a weak base and its salt, the relations are similar with K_b and K_b^1 replacing K_a and K_a^1 in the equations.

If but one buffer combination is present, the plot of buffering power, β, versus pH gives a symmetrical curve with maximum at $pH = pK_a^1$. The height of the curve on either side as well as at the peak is directly proportional to the concentration of buffer. This is a very important consideration, for it imposes a restriction on the buffer power curve and hence upon the slope of the titration curve. In the general case of several buffer systems together in a solution all sorts of skew effects may result but each system has its own symmetrical curve (van Slyke, 1922). It is obvious that if a buffer system of known concentration and of known K_a^1 is taken, the buffer power versus pH curve can be calculated.

The points of Figure 96a give indication of at least two regions of maximum slope, one near pH 4.15 and the other near pH 6.8. The slope below pH 3 is uncertain as will be discussed later. A search of the literature revealed that Bishop, Briggs and Ronzoni (1925) found a high concentration of phosphorus in the blood of honeybee larvae. It appeared likely

that part of the buffering power of the contents of the ventriculus of the adult honeybee might be due to the phosphate system. To test this possibility, analyses of the ventricular contents were made. Since pollens are rich in phosphorus, (Elser, 1928; Elser and Ganzmüller, 1931), it seemed wise to put the bees on sugar solution for several hours in order to clear the ventriculus of everything but the sugar diet and the digestive juices. The liquid contents of the ventriculi of several dozen bees were collected, and measured known volumes were diluted with distilled water and filtered through tight filter paper. The solutions were then evaporated in the presence of sulfuric acid. During charring the odor of caramel was very noticeable. The solutions were cleared with nitric acid, and the excess expelled. The presence of phosphate was then determined by the method of Fiske and Subbarow (1925) which one of the present authors found to be very satisfactory for small amounts of phosphate in mouse blood (de Aberle, Hoskins and Bodansky, 1927). Standard phosphate solution was prepared from recrystallized potassium diacid phosphate. Two determinations on the same lot of ventricular fluid from about fifty bees showed that 0.00716 cc. contained 0.01083 and 0.0100 milligrams of elementary phosporus from which it may be calculated that the phosphate concentration was 0.049 and 0.045 M. An entirely fresh portion of ventricular fluid was then collected and tested with the result that 0.009 cc. contained 0.0121 mg. of phosphorus, or the phosphate concentration, was 0.044 M. The average of these three determinations gives 0.046 M as the phosphate concentration in the ventricular contents of the honeybee after feeding on sugar solution for several hours.

In many biological fluids the phosphorus is partially in organic compounds, especially lecithin. Thus Bishop, Briggs and Ronzoni (1925) found over seventy per cent of the phosphorus in the blood of honey bee larvae to be in the lipoid portion. To test this point with the ventricular contents of adult honey bees, a portion of the fluid was diluted with distilled water and thoroughly extracted with three successive portions of ethyl ether. The ether was removed, evaporated and the residue tested for phosphorus as described before. No detectable amount was found in two entirely different tests.

From the data that the phosphate concentration in the ventricular contents is 0.046M and that this is all in inorganic form, it is possible to calculate the buffering power due to that substance. This may be readily done by using Equation 17 of van Slyke's article (1922):

$$\beta = 2.3 \left\{ \frac{K_a' C [H^+]}{(K_a' + [H^+])^2} + [H^+] + [OH^-] \right\}.$$

C is the molecular concentration of phosphate, 0.046M. K_a^1 is taken as 1×10^{-2} over the pH range 2.0 to 4.0, where the buffer system consists of phosphoric acid and its dihydrogen salt. Over the pH range, 4.5 to 8.0, K_a^1 is taken as 1.4×10^{-7}, corresponding to the buffer system dihydrogen phosphate and monohydrogen phosphate. The calculation can be made more easily by use of the U curve in Figure 9 of van Slyke's article, according to the method explained there. The results are shown in Figure 96a. It is obvious that the phosphate system contributes but little to the strong buffer effect indicated by the points near pH 4.15 in Figure 96a, but that the maximum in buffer power of phosphate at pH 6.8 coincides with that indicated at the same pH in Figure 96a.

The assumption then was made that the total buffering power of ventricular fluid is due to the phosphate system and to one other unknown system, having a maximum effect at pH = 4.1, i.e. having $pK_1^1 = 4.1$, or $K_1^1 = 8 \times 10^{-5}$. The other missing datum was the concentration of this unknown buffer. Put in another way, the slope of the titration curve at pH = 4.15 needed to be known, since by van Slyke's equation given above, it is directly proportional to the concentration. The data of Figure 96a was plotted to a large scale and the slope, β, measured several times. The average value of β at pH 4.15 was 0.0944. Since at this pH the phosphate system contributes 0.0008 to this slope, the value of β for the unknown buffer is 0.0936. When $pH = pK_a^1$, the concentration, $C = \frac{\beta}{0.575}$ (eq. 3), from which it follows that the concentration of the unknown buffer is $\frac{0.0936}{0.575} = 0.163$ M.

From the data on the concentration and the dissociation constant of the unknown buffer it is possible to calculate the buffering power, just as was done for the phosphate system. It is necessary to note that van Slyke's equation 17 must be used in the form:

$$\beta = 2.3 \left\{ \frac{K_a^1 C[H^+]}{(K_a^1 + [H^+])^2} \right\}$$

because the buffering effect due to hydrogen or hydroxyl ions was allowed for in calculating the phosphate buffer curve. The results are shown in Figure 97b. By adding together the buffering powers of the two systems a value is obtained for the total buffering power of ventricular fluid at each pH, as shown in Figure 97c. Proof of the accuracy of the determinations and assumptions which have been made depends upon the agreement between the titration curve, Figure 96a and the buffer power curve, Figure 97c. This agreement may be examined in two ways.

The maxima and minima of Figure 97c as indicated by the arrows show that inflections should occur in Figure 96a at the same pH values. Inspection of the latter curve shows this to be true. Also the slope of this curve at each point should agree with the value of the ordinate at each corresponding point of Figure 97c. It is difficult to measure the slope of a curve in a small plot but careful determination of the slope of the curve in a large scale plot of Figure 96a showed that the slope agrees very closely with that indicated by Figure 97c. Below pH 3 coagulation of some

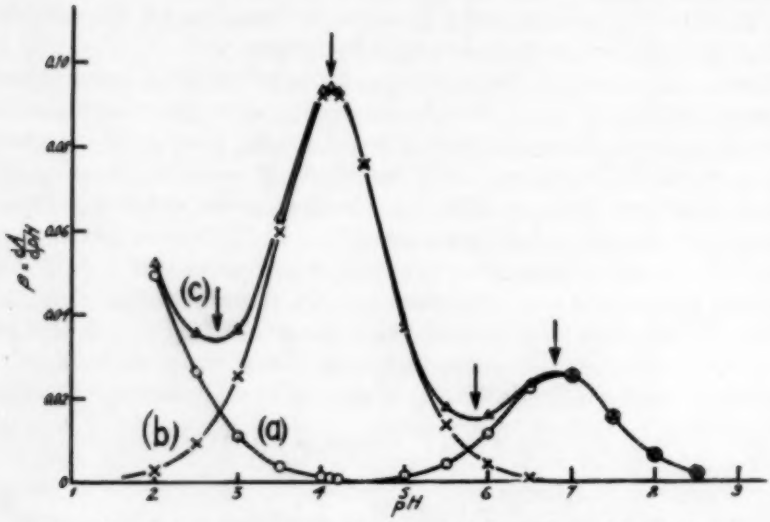

FIG. 97.—Buffer power curves for ventricular contents. (a) calculated for phosphate concentration, 0.046 molal; (b) calculated for unknown buffer system, 0.163 molal; (c) total buffer power curve (experimental) as calculated from Figure 96.

substance, possibly protein, followed the addition of acid and the final value was very uncertain. Something more than a mere stoichiometric reaction with a buffer system occurred. Hence only one average value is shown in Figure 96a to indicate the general direction of the curve.

A few determinations were made with the sugar solution used in feeding the bees. This had little more buffering power than distilled water as shown by Figure 96b. However, it was possible that a buffer substance might be formed from sugar in the ventriculus. Bees were kept on a diet of distilled water for ten hours, by which time they were visibly weakened. The ventricular contents were then treated with solutions of acid or base and the resulting pH determined. Only a few preliminary deter-

minations were made but they indicated that the fluid had approximately the same buffering power as when the bees were kept on natural or sugar diet.

LETHAL DOSE OF ARSENIC AND COMPARISON WITH OTHER INSECTS.—A study of the literature brought out that there is little quantitative data available regarding the amount of arsenic required to kill a honeybee and the length of time before death occurs. Troop (1918) found 0.5 γ As_2O_3 (0.4γAs) to be a minimum lethal dose. Price (1920) regarded a lethal dose to be less than 0.5 γ As_2O_3 (0.4 γ As). Cook and McIndoo (1924) reported that the minimum lethal dose of arsenic acid to a honeybee was 0.76 γ (0.5 γ As). The work of Hilgendorff and Borchert (1926) showed that bees found dead after airplane dusting contained from 0.05 to 0.4 γ As_2O_3 (0.04 – 0.4 γ As). Hermen and Brittain (1933) judged, from analyses of bees found dead both in the field and in cage tests, that over 0.08 γ of arsenic calculated as the element is a lethal dose. No clear distinction was drawn by any of these workers between trivalent and pentavelent arsenic, though for some insect, e.e., the silkworm (Campbell, 1926a) there is a great difference in toxicity. Also the arsenic remaining within the body of a bee at death is not necessarily an indication of the size of a lethal dose by mouth for some may pass through the digestive tract without adsorption. In the present work abnormal defecation was noted with the poisoned bees. The estimation that the fatal dose of soluble arsenite is between 0.1 and 0.2 micrograms of elemental arsenic is somewhat lower than those made by most of the previous workers but they did not observe the bees over so long a period after feeding.

Since the bees of the colony used in these experiments weighed 0.20 gms. on the average, the minimum lethal dose is between 0.0005 and 0.001 mg. As per gram of body weight. Compared with many other insects, the honeybee is extremely susceptible to arsenical poisoning. Several recent publications have given data on the median lethal dose by which is meant the amount necessary to kill fifty per cent of the experimental individuals. This will necessarily be less than the minimum lethal dose which by definition kills all individuals. But for the present purpose the two dosages will suffice for a rough comparison. Campbell (1926a) found the median lethal dose of neutral sodium arsenite for the silkworm to vary from 0.0075 mg. As per gram in the second instar to 0.0125 mg. As per gram in the fifth instar. Campbell (1926b) reported the median lethal dose of alkaline sodium arsenite to be 0.02 mg. As per gram for the tent caterpillar, *Malacosoma americana* and for the larva of the moth, *Datana ministra*. Richardson and Haas (1931) gave data

showing the median lethal dose of Paris green to be not less than 0.04 mg. As per gram for the larvae of the Colorado potato beetle. Richardson and Haas (1932) reported the median lethal dose for the grasshopper to be, for monosodium arsenite 0.051 mg. As per gram, for trisodium arsenite 0.087 mg. As per gram, for Paris green, 0.04 mg. As per gram. Lastly Pearson and Richardson (1933) found the median lethal dose for arsenious acid and trisodium to be 0.14 mg. As per gram of body weight for the housefly.

Data on the pH of the contents of the digestive tract of the honeybee are very scarce. Snodgrass (1925) says that the contents of the digestive tract have been said to be alkaline during digestion and neutral or but slightly alkaline at other times. He does not cite authority for this statement. Krüger (1925) in a paper on the reaction in the digestive tracts of several invertebrates reported that by a colorimetric method he found the pH of the honeybee's digestive tract to be 8.4 to 9.8 but he did not mention for which region this was found. It seems possible that his indicator was not acting as a hydrogen ion indicator, expecially since in the present experiments the indicator brom cresol green was found not to behave normally. Indirect evidence for the validity of the experimentally determined value, 6.2–6.3, for the normal pH of the contents of the ventriculus is afforded by the results of other workers on the enzymes present. Though a wide variety have been reported in the bee's digestive tract by various writers, only invertase, pepsin and trypsin were found by Brown (1928) who took care to reduce bacterial action to a minimum. Since carbohydrates are so important in the food of the bee it is probable that the normal pH of the ventriculus will be within the optimum range for invertase. Apparently the optimum pH range for this enzyme of the bee has not been determined but Wigglesworth (1927b) in a careful study of digestion in the cockroach found the invertase of that insect to have optimum activity at pH 5.9 and to be practically inert above neutrality.

Bishop (1923) has reported that the pH of the body fluid of honeybee larvae is 6.8 with variation from 6.77 to 6.93. This agrees closely with the present results on the blood of adult bees of pH 6.70 with variation in eight determinations from 6.63 to 6.85. It is probable that both fluids are strongly buffered by the phosphate system whose maximum effect is exerted at pH 6.8. Confirmation of this is afforded by determination of the phosphate content of adult bee blood.

Phosphate in Bee Blood.—A solution of 0.014 cc. blood in distilled water was analyzed for phosphorus by the method described before and found to contain 0.025 mg. P. Hence the original blood was 0.058 M

with respect to a phosphorus compound. Another 0.0115 cc. volume contained 0.0216 mg. P, whose concentration accordingly was 0.061 M. These two blood samples were obtained from bees fed for a day on sugar solution. Analyses on bees directly from the hive gave slightly higher phosphorus concentration, 0.065 M, and it was noticed that only smaller volumes could be gotten as compared to the bees fed on sugar solution. Attempts to extract an ether soluble phosphorus compound e.g., lecithin, were unsuccessful from which it may be concluded that most of the concentrations given above were due to inorganic phosphate, though some phospho proteins may have been present. It should be noted that bee blood is slightly richer in non-ether soluble phosphate than is the fluid of the ventriculus which was 0.046 M with respect to phosphate. Bishop, Briggs and Ronzoni (1925) found the blood of honeybee larvae to contain 31 milligrams P per 100 cc. (0.01 M) and 83.5 mg. lipoid P per 100 cc. (0.027 M). It is to be expected that organic phosphorus would be present in the fluid of a rapidly developing larva, whereas the small size of the fat body in an adult worker bee is an indication that fat metabolism and hence lipoid phosphorus are unimportant at that stage.

Phosphate in Excreta.—The occurrence of inorganic phosphate at the high concentration of 0.046 M within the digestive tract gave rise to question as to its source and later disposal. Since this data was obtained on bees fed on sugar solution for many hours it seemed impossible for the phosphate to have come from pollen. Microscopic examination of the ventricular fluid did not reveal any pollen grains, though yeast cells were fairly plentiful. Hence it is to be concluded that the phosphate was a constituent of the "digestive juice". If all, or most, of this compound was excreted a very serious physiological problem would be involved in maintaining such a high concentration. Analyses of excreta were made to obtain information on this point. When bees that have been confined, either within a hive or cage, are liberated they usually defecate at once. Accordingly, bees were set loose upon a clean glass plate placed before a window and when fecal material was deposited upon the plate it was drawn up in a capillary pipette before appreciable evaporation occured. When a sufficient volume was collected it was analyzed as before and an average phosphate concentration of only 0.005 M was found. A comparison of the concentration of phosphate in the ventricular contents (0.046 M) with that in the excreta (0.005 M) shows that about ninety per cent is reabsorbed. This sheds light upon the question of whether absorption occurs after liquid leaves the ventriculus, and agrees with the opinion of Snodgrass (1925, p. 177) that absorption of

food materials derived from pollen occurs largely in the fore-part of the hindgut, sometimes called the small intestine. No study has been made of the buffering power of the excreta, but removal of phosphate, whose maximum buffering power is at pH 6.8, would tend to shift the pH toward higher acidity (cf Table 1). It appears that there exists a "phosphate cycle" in the digestive tract and that phosphates have little to do with determining the pH of the feces. Since these contain liquid from the Malpighian tubules as well as that from the digestive tract, a very complex mixture exists.

Buffering Power of Ventricular Contents.—The only existing data on buffering power of the contents of an insect's digestive tract appears to be that of Swingle (1931), who worked with the fore, mid, and hind guts of the Japanese beetle larva. His results are given for only the short range between pH 8.0 to 9.5 and, when plotted in a manner similar to Figure 96a, give an approximately straight line of slope $\beta = 0.148$ for the pH range above. This is higher than the maximum value of β for the honeybee (0.0944) as is to be expected, since Japanese beetle larvae live in soils of very varying pH and of quite strong buffering powers. The remark of Pearson and Richardson (1933) that ingestion of arsenic by the housefly might *induce* secretion of a buffering substance, evidently does not account for the state of affairs in the honeybee and in the Japanese beetle larva in whom a condition of strong buffering power is normal. However, the irritation caused by ingestion of arsenic probably does lead to an extraordinary secretion of buffering substances. This would account for the fact that the arsenical solution buffered at pH 9 was as toxic as the acidic solution, though the buffer power of the *normal* ventricular contents is low in the alkaline range and hence might be expected to cause but slight lowering of the pH of the ingested alkaline liquid.

In many biological fluids the carbonic acid-bicarbonate system contributes appreciably to the buffering power. Apparently this is not true in the case of the ventricular contents of the adult honeybee, for no evidence of this is shown near pH 6.1 which is the point of maximum buffering effect for that system ($K_a^1 = 8 \times 10^{-7}$, or $pK_a^1 = 6.1$; van Slyke, 1922, page 562). A similar condition was found by Bodine (1926) in the blood of grasshoppers. He remarked that low carbonate concentration is to be expected in any insect having tracheal respiration. On the other hand, Bishop (1923) found the total carbonate concentration in the blood of honeybee larvae to vary from 26 to 35 volume per cent which is nearly as high as in animal or human blood. This is to be expected since ventilation of such larvae must be very inefficient because

of the manner in which they are enclosed. Whatever proteins are present in the ventricular contents of the adult bee appear to contribute very little to the total buffering power, at least over the range pH 3.0 to 9.5.

It seems peculiar that the normal pH of the ventricular contents of the honeybee is not at or near a region of maximum buffering power as shown in Figure 4a. The low buffer effect near pH 6.3 is probably connected with the fact that a total range was found from pH 6.05 to 6.43 among all the bees tested. This variation apparently is not connected with the type of food for no consistent difference occurred between bees from the hive and those fed on sugar solution. It seems more likely that the stage of digestion accounts for the variations in pH for the ventricular contents of bees fed only on distilled water overnight had very constant pH of 6.2–6.3. Wigglesworth (1927a) found a variation of 0.4 units in the normal pH of the contents of the midgut of the cockroach and attributed this to variation in the food. He did not study the effect of time after feeding.

NATURE OF THE UNKNOWN BUFFER.—The chemical identification of the unknown buffer system has not been attempted and no conclusion can be drawn. By Equation 1, $K_a' = \frac{K_a}{\gamma_s}$ from which it will be noted that the dissociation constant, K_a, can be calculated from the value of K_a', 8×10^{-5}, only if the degree of dissociation of the buffer salt is known. In a fluid containing so much dissolved material any salt will fail to ionize completely and the salts of organic acids may be but slightly ionized. Making the assumption that γ_s is between 0.5 and 0.9 the value of K_a would be between 1.6×10^{-4} and 0.9×10^{-4}. It would be useless to list the organic acids which come within this range but Wigglesworth (1927a) found the contents of the crop of the cockroach to give the test for α-hydroxy acids with ferric chloride and suggested the possibility that lactic acid was present. Both lactic acid and glycollic acids have dissociation constants (Kolthoff and Furman, 1931, p. 450) within the range given above. Both of these acids are supposed to have an important part in the digestion of carbohydrates, which comprise most of the food of the honeybee.

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RELATION BETWEEN THE NECTAR CONCENTRATION IN FRUIT BLOSSOMS AND THE VISITS OF HONEYBEES

By GEORGE H. VANSELL, *Associate Apiculturist, Bureau of Entomology, United States Department of Agriculture*

Evidence now accumulating amply explains certain peculiarities of bee behavior recorded in earlier pollination data. Honeybees have often been observed to prefer different blossoms under different conditions of time or place. Field and laboratory studies on the behavior of bees in pollination in California, pursued through three consecutive deciduous-fruit blossoming periods (1932–4), indicate the influence of variation in the quality of the nectar irrespective of its quantity. In the Sierra foothills, for example, Bartlett pear blossoms are eagerly visited each morning until approximately 10 o'clock, when they may be practically abandoned for other blossoms; likewise, a shift from plums to manzanita frequently occurs near mid-day.

The open structure of some fruit blossoms permits dilution of the nectar by rain and by dew at night. In the case of apricot blossoms, which are particularly subject to this dilution, bees will frequently not take nectar until the lower humidity of daytime removes sufficient water to increase nectar concentration sharply. A low concentration occurs at night, except when there is a dry north wind; and on cloudy, humid days the nectar remains continuously unattractive. Certain plum blossoms of the open type are likewise neglected at times. Almond nectar, however, being well protected by the blossom structure, never appears to fall below the attractive concentration.

In general, among the deciduous fruits at Davis, Calif., the apple ranks highest in nectar concentration. Since, however, it blossoms later than most of the other fruits, it does not attract many bees away from blossoms with poorer nectars. In certain localities mustard, because of its rich nectar, is known to interfere with plum pollination.

During these studies the sugar content of nectars was measured with an Abbé refractometer equipped for direct sugar reading. Hand collection of the nectar by the use of pipettes was sometimes very slow, or even impossible, but the honey stomach from nectar-gathering bees always afforded an ample supply. Nectar obtained in these two ways checked rather closely whenever the weather was conducive to free field activity of the bees. Table 1 shows the sugar concentration of several fruit nectars as obtained in this experiment.

The presence of nectar-producing nonfruit blossoms within and near an orchard has a definite bearing on honeybee visitation to fruit blossoms.

Mustard, chickweed, and manzanita nectar rank with the fruits near the head of the list in Table 1. Fruit growers have frequently stated that bees do not work certain fruits, and in many localities it indeed appears possible to specify a time of day when this is true. In studying the habits of bees, each day must be considered separately, because every hour may bring new associations in the field. Although the shift from one species or variety of blossom to another is rather systematic, the same routine may or may not be repeated on successive days.

TABLE 1.—SUGAR CONCENTRATIONS OF SOME FRUIT NECTARS

Fruit	Average sugar concentration, in per cent[1]
Apple	35–55
Cherry	20–50
Almond	20–40
Peach-nectarine	20–25
Plum	10–40
Apricot	5–25
Pear	2–17

[1]These figures represent composite averages from several species and varieties under variable conditions. Figures taken when there was a dry north wind are not included.

Under field conditions at Davis and Camino, Calif., deciduous-fruit nectar with less than 5 per cent sugar was not attractive to bees. Under some other set of conditions the minimum concentration for attractiveness would probably be quite different. Table 2 illustrates the daily variation in nectar concentration at Davis.

TABLE 2. VARIATION IN PLUM-NECTAR CONCENTRATION AT FOUR PERIODS IN ONE DAY (MARCH 31, 1934) AT DAVIS, CALIF.

Time of day	Sugar concentration, per cent	Relative humidity, per cent	Temperature, °F.	Weather
7–8 a. m.	6.2	100	52	Heavy dew and tule fog in early morning.
9:40 a. m.	8.1	85	59	
2:00 p. m.	25.8	55	70.5	Day fair and mild.
2:50 p. m.	24.1	53	71	

Frequently in the early morning, when nectar concentration is low, bees visit blossoms for pollen only, but as the day advances nectar gathering becomes their chief or sole interest. Throughout these studies Bartlett pear seemed to offer no attraction as a source of nectar. Although bees were abundant on these blossoms each morning, they became scarce as the concentration of nectar in apricot or plum increased. Observers recording all the insect visitors to certain Bartlett trees found that, when nectar was available outside the pear orchard, 81 per cent of the honeybees on pear arrived before 11 o'clock in the morning. Blowflies and ants, however, appeared to find the ill-smelling pear blossoms highly attractive.

Field counts of the bees' visits to the blossoms have shown that concentration of the nectar sugar is the chief factor involved in determining which species or variety the honeybee will work most freely for nectar. With the data in hand it is possible to explain some of the "mystery" in the sudden shifting of bees from one plant to another. A complex situation clearly exists, giving rise to competitive bidding for visitors. Blossom structure, in particular, causes a variable rate of change in nectar concentration, which quickly influences bee activity. The apparent sensitiveness of honeybees to rather slight differences in concentration is worthy of note.

THE NUMBER OF GENERATIONS OF THE BEET LEAFHOPPER UNDER NATURAL CONDITIONS

By E. D. BALL, *University of Arizona, Tucson*

The writer worked out the life history of the beet leafhopper as it occurs in the sugar beet fields at Logan and Lehi, Utah, and found a single annual generation on the beets. (Ball '07) (See Fig. 98).

The adults flew into the beet fields at about thinning time, from late May to the middle of June, and laid eggs through June, July and August. The nymphs began to appear in small numbers by July 10, in large numbers by the last of July and on through August. Adults began to appear by the middle of August and continued to appear through September. The earliest adults to appear were caged but they laid no eggs. A large number were caged in the middle of September but they laid no eggs. Most of them left the fields soon after this and before the beets were harvested. Dissection of the females at different times in the fall showed that there had been no eggs developed.

The writer visited the beet fields in Utah, Idaho, Oregon, and California, and found very similar conditions, the leafhoppers frequently appearing about thinning time and usually leaving the field before harvest. The time of appearance was sometimes as much as a month or two earlier in the warmer regions, but the beets were harvested just that much earlier so there did not appear to be any possibility of more generations on the beets. In Glendale, Arizona, the leafhoppers appeared on the beets in March, but the beets were usually harvested in June and July so that the actual time on the beets was often less than in Utah.

The statement was made "that the beet leafhopper was apparently single brooded" with an extremely long egg laying period such as is often found in single brooded species, and a chart was presented showing its

range in time of appearance on the beets, and indicating a single complete generation as occurring in the beet field.

Stahl ('20) worked out the life history of the beet leafhopper at Jerome, Idaho in the latter part of 1913 and 1914 and found a single generation on the sugar beets, as follows: (See Fig. 98). Adults first appeared in the field June 6, before the beets were thinned; in fact before

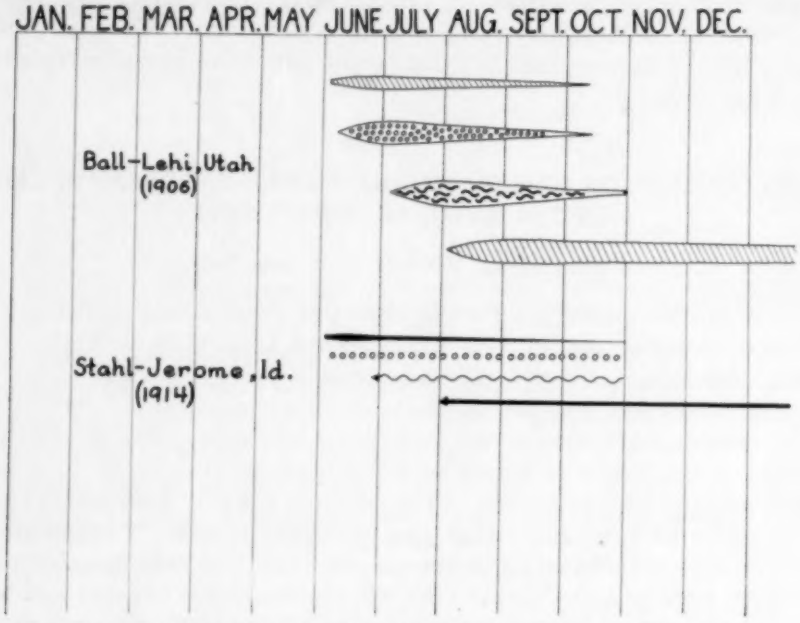

FIG. 98.—The life history of the beet leafhopper on the sugar beets in Utah and Idaho.

some of them were up; egg laying began at once and continued until late October. The first nymph appeared in a cage June 28. Copulation in this generation was not observed until late in the fall. On October 12, 1913, a large number in a cage were copulating but they did not lay eggs.

In the same publication, Stahl states that "experiments conducted at Spreckles, Calif., demonstrated that there were unquestionably at least two generations annually in that locality". A little later, he discusses the "possibilities of a new brood on wild vegetation before migration into the beet fields", and states that "observations and cage experiments have proved that such a brood occurs". If there are two broods at Spreckles and one occurs on wild vegetation, there will be only one brood on the sugar beets. He gives no detailed data but states

that "adults and nymphs are most abundant in the fields during August. At harvest time, they are scattered and no doubt a large number perish".

The above three life history studies are all that have been made upon sugar beets *in the field*, and they all agree in the one essential—that there is but one generation *on the beets*. It is true that Stahl states "that under conditions more favorable than was usual, a third and even a fourth brood were obtained." The significance and basis of these statements will be discussed after other evidence has been considered.

Stahl at Riverside, and Severin at Manteca, have carried on extensive and extremely valuable breeding experiments with the beet leafhopper. These experiments were conducted under entirely artificial conditions of both food and environment, and cannot be used to interpret the normal reactions of the leafhopper either in a sugar beet field or on its native breeding ground.

For one thing, they were fed on a constant succession of young and vigorously growing beets throughout. Secondly, they were under artificial conditions of temperature and humidity. Severin's illustrations show a greenhouse and the explanation of the figures calls attention to "an electric lamp . . . . illuminating and heating the interior of the cage during foggy days".

It is unfortunate that a more complete record of the actual temperatures to which these insects were subjected was not recorded as it would have materially increased the value of the record. They are, however, very illuminating in a number of ways and, in connection with the normal temperatures of the two locations and Carter's constant temperature result, furnish much information that can be used to show the fallacy of a number of wild statements that have been made.

Severin ('30) working at Manteca, caged fifty females taken from cultivated fields February 12. These were transferred to a new beet each week so that the progeny of each week's egg laying could be determined separately. The date of the first nymph to appear in each cage, the first adult and the last, and the number appearing each day were recorded. From this information could be determined the minimum egg period, the minimum and maximum nymphal period and, therefore, the average nymphal life. From these records, the life history chart (Fig. 99) was constructed. This shows that egg laying continued for nearly seven months; that nymphs were in abundance from May to August and ran on into October, although those just hatching were killed by rains October 1; that adults of the first brood appeared in enormous numbers during June and July and continued to appear until October; that nearly all these adults lived until August or September and that the last of them

in the cages survived until the middle of April, a nine or ten month period.

This is a very complete record of one brood of leafhoppers, and this single brood covers fully the normal growing period of sugar beets in this region. The egg laying extended for more than six months; nymphs were in the fields for six months; the adults were practically all alive until after the middle of August which, as Stahl has stated, is the normal

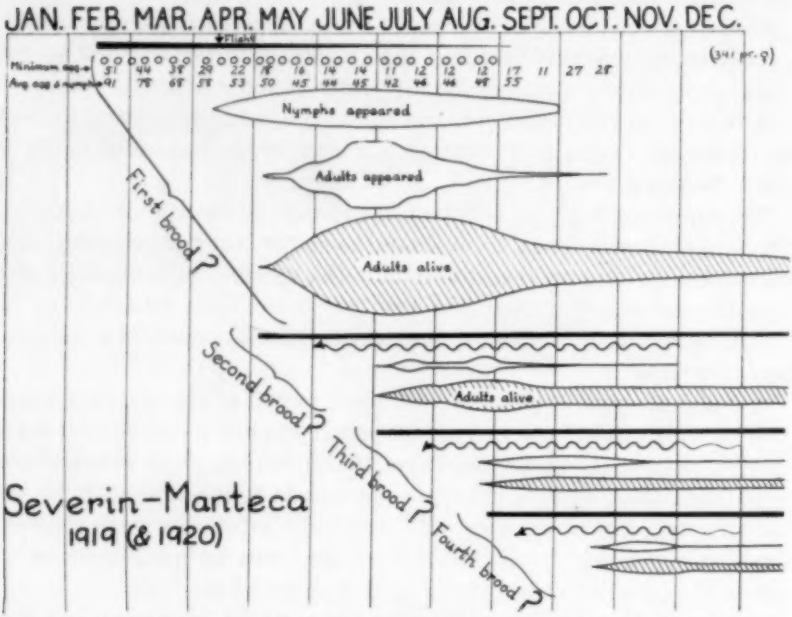

FIG. 99.—The life history of the beet leafhopper under artificial conditions of fresh food and housing in California.

climax of the season's infestation. Eggs laid after the middle of August require an average of fifty days to mature, or until the middle of October. Most sugar beet fields would have been harvested before this time and the eggs or nymphs destroyed. The writer's observations have been that there are few leafhoppers in the field at harvest time, the great majority of them having disappeared some time before, probably hastened by the maturity of the beet.

The so-called second, third and fourth broods of this record are not broods at all in any true sense. They are a sort of biological "*tiddle-dy-winks*" that divert time and attention from the real problems at hand. The material to start the so-called second brood was taken from a few

extremely early specimens, due to an extraordinarily warm May with temperatures more than five degrees above normal. In a normal season, the first adults would not have appeared until two weeks later.

It would have been just as accurate to have selected the last adults of that generation that appeared in the middle of October. With the normal pre-oviposition period, the first eggs would have been laid in November. With normal temperatures, they would not have hatched, or if they did hatch, the little nymphs would have perished in the first storm. The temperature in November is nearly the same as in February and in February, Severin shows an average egg-to-adult period of 91 days, with the temperature increasing nearly fifteen degrees during the period. What would it be from November 1 on, with the temperature falling seven degrees the first month and only regaining the same level in the third month?

Severin states that "eggs deposited from November 1 to January 15 failed to hatch". In a second experiment, "a few eggs deposited from December 15 to 31 and January 1 to 15 hatched, but the nymphs died, out of doors". He adds also that "during the winter, there was a high mortality of the nymphs which hatched from eggs deposited during September and October". He also records that "the last eggs (of the first brood) hatched on September 27 but the nymphs were killed by 0.47 inch of rain on September 30. Under these circumstances, there would of course have been no second brood at all if he had taken the last adults to appear, and yet that method of computation is exactly as fair as the other.

The correct method of determining the number of true generations under these conditions would have been to use a given number (say 100) of adult hoppers from the great flight of April 14, which would then have represented the normal time and method of infestation of the region at a time when there were sugar beets to infest. Using the data found in this study (as shown in Fig. 99) it has been possible to construct a chart (Fig. 100) which shows what would have happened if this had been done. This shows one complete generation during the beet growing season and a partial second generation whose magnitude would depend upon the time the beets were harvested. With the normal harvest in August, September and October, this partial generation would be very small. If the harvest was delayed until the last of October or into November, there might be time for about half of the second generation to develop to maturity and even for a trace of the tiddle-dy-winks third generation to appear.

But we must keep clearly in mind that this is a purely artificial or theoretical picture, and that it does not apply to any beet growing re-

gion or to any natural breeding ground; that there is no region with a weekly succession of fresh, succulent vegetation, nor any region where the leafhopper is able to breed the year around. Even the most optimistic California booster would hesitate to claim a fresh development of sugar beets each week in the year and certainly he would not want to assert that there were no rain storms in the winter season.

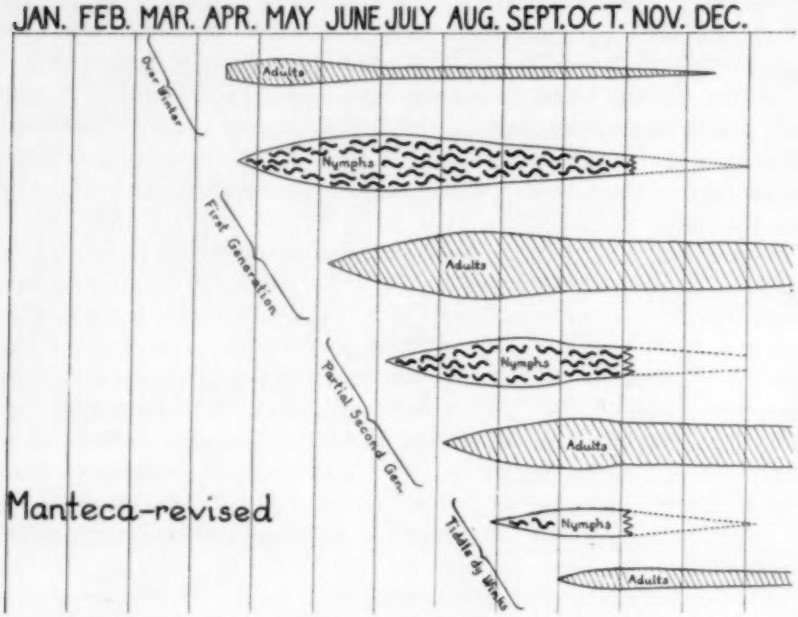

FIG. 100.—The possible progeny of the beet leafhoppers of the great flight of April 14, 1919 (Calculated from data of Fig. 99).

Even in Stahl's work at Riverside, where winter temperatures are seven degrees higher than those at Manteca (Stockton), his results show little or no development during the winter period. It is also well to remember that, in the warmer parts of California and Arizona, sugar beets are planted in the fall and matured in the early summer, thus escaping the leafhopper damage—a very convincing argument that the leafhopper is not active in the winter period, even in these warmer regions.

These experiments do show conclusively that the beet leafhopper will continue to reproduce indefinitely if a continuous change to young and rapidly growing food plants is provided and satisfactory temperatures are maintained. This same result has been found in Plant Lice by Ewing and in Protozoa by Jennings. There is, however, no experimental evi-

dence that the beet leafhopper continues to reproduce when feeding on normally maturing sugar beets or even on the more rapidly maturing vegetation of the deserts. The writer's cage experiments in Utah and those of Stahl in Idaho show that, under the conditions obtaining in those regions, leafhoppers which had matured on the beets in the field did not deposit eggs nor even develop them, even where they had emerged and had been feeding on the sugar beets many weeks before being caged.

The Beet Leafhopper Belt

The whole life history situation will be much clearer and more easily visualized if we can definitely establish the belt of temperature variations within which the insect is able to maintain itself in the normal struggle for existence. Carter ('30) carried out an elaborate series of constant and alternating temperature studies with the following roughly averaged results:

Mean temperature	Pre-ovip. period	Incub. period	Develop nymph	Total time egg to egg
100	—	7	13	29
90	—	8	16	33
85	9	8	—	36
80	—	12	23	44
75	10	14	23	47
70	—	21	—	—
65	60	34	(rate of)	(rate of)
60	80	—	(55) (no)	(150) (no)
			(70) (no)	(190) (no)

From the table, we see that eggs began to develop in the ovaries at 60 degrees but none were laid. Nymphs kept at this temperature grew at a rate that would have taken them 70 days to mature but none of them survived. At 65 degrees, eggs developed in about 60 days, were laid and took 34 days to hatch. Nymphs developed at a rate that would have taken 55 days to mature but none of them survived. In fact, it was not until a temperature of 75 degrees was used that nymphs continued to develop to maturity. These figures indicate that this insect has become adapted to developing eggs in the spring when the temperatures range between 60 and 70 but that the hatching of these eggs is delayed until temperatures well above 70 degrees are reached, when nymphal development can proceed with safety.

Studies of the grape leafhopper and the potato leafhopper, both of which have definite spring flights, have shown that the flight period is a very good index of the advent of favorable temperatures for their successful development. The enormous flight of the beet leafhoppers at Manteca in 1919 was April 14, when the temperature was just under 60

degrees. The outstanding flights in Utah and Idaho occurred the last of May or early in June, again with temperature just under 60 degrees. September closed their development in Utah and Idaho and October slows them down in the San Joaquin Valley in California, again indicating temperatures just below 60 degrees as limiting. All these instances approximately fix the lower limit of the beet leafhopper belt just below 60 degrees. (Figs. 101 and 102.)

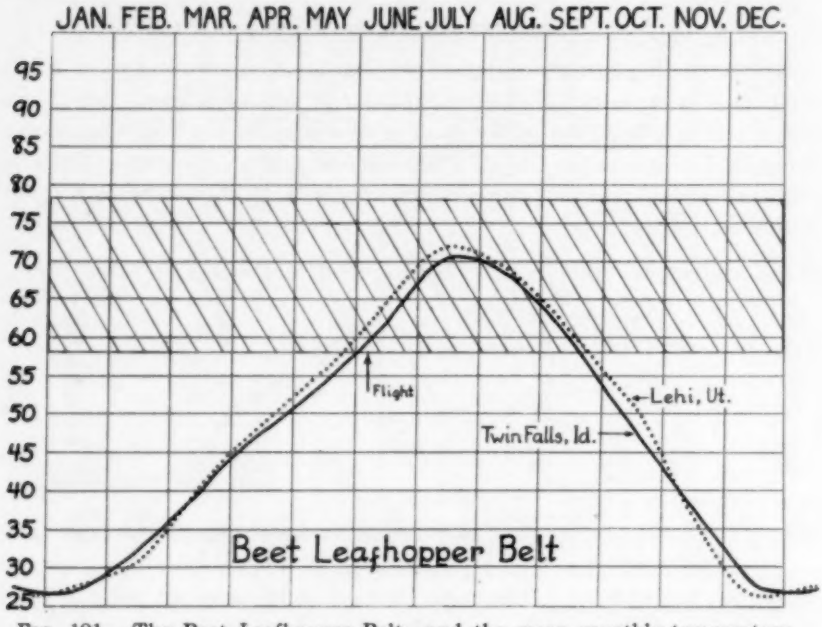

FIG. 101.—The Beet Leafhopper Belt—and the mean monthly temperature curves of the beet growing regions in Utah and Idaho.

The fixing of the upper limit of the belt is not important for this study, for the highest mean temperatures of the regions under discussion all fall well within the normal range of adaptation of other insects that have been studied. The normal range is very close to 20 degrees and that is also the normal range of diurnal fluctuation in temperature. There may be a long time adaptation involved. If the range is approximately 20 degrees, then the upper limit of the belt would fall just below 80 degrees. This would indicate that summer temperatures in the Bakersfield region, the region around Phoenix and in the Imperial and Death Valleys would be inimical to the development of the insect during that period, and this agrees with the writer's observations.

Is a "Generation on the Deserts" Before the Spring Flights Possible?—After definitely fixing the lower limits of the favorable temperature belt from all data available and considering that Stahl at Riverside and Severin at Manteca have established beyond question that it takes from five to seven months in the warmest period of the summer to develop a complete generation of this insect, it does not seem possible that any one would be foolish enough even to suggest that there

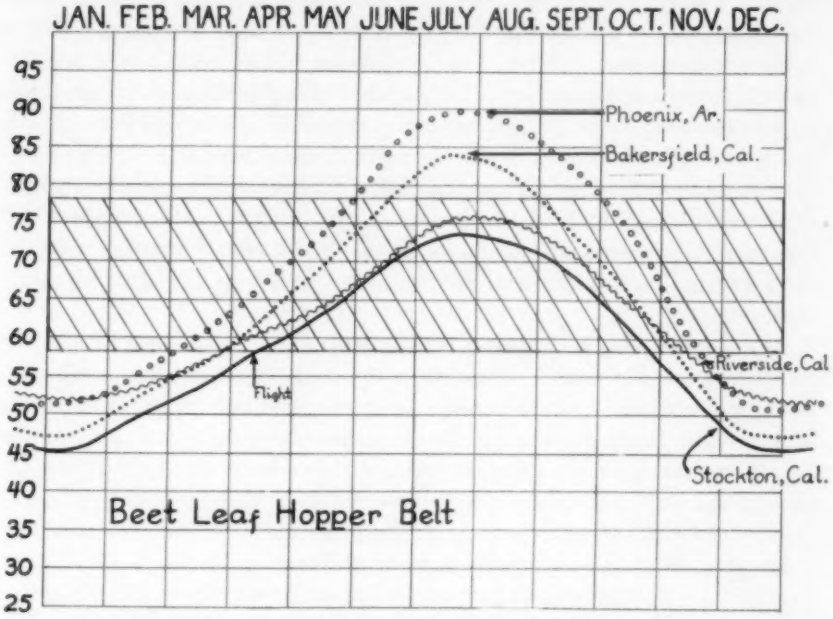

Fig. 102.—The Beet Leafhopper Belt and the mean monthly temperature curves of the warmer sugar beet growing regions of California and Arizona.

was a "generation on the desert" before the spring flights. Severin, beginning the middle of February in an exceptionally warm spring with sheltering cages, had scarcely produced a nymph when the spring flight occurred. Stahl's record at Riverside with winter temperatures 7 degrees warmer, (and much warmer than the warmest place in the San Joaquin Valley) was very little farther along. If these men could not produce a single leafhopper to take part in a flight at that time, where were they produced?

Carter ('30) spends many pages in attempting to show that the surface soil temperatures in Idaho are warmer than the air temperatures and that the accumulation of the few hours of favorable temperatures in the

warm days would be enough to develop a generation before the spring flights. One glance at the spring temperatures shown in Fig. 101 should be enough to dismiss that idea. If this were true in Idaho, then certainly the leafhopper would be breeding freely all winter in the San Joaquin Valley, where the temperatures are 15 to 20 degrees higher; but such is not the case, as every one knows. If the soil temperature had any such effect in Idaho, what would it have in Riverside and Phoenix with their cloudless skies and winter temperatures 25 degrees higher, and yet the beet leafhoppers do not start to develop there until the temperatures approach the lower limit of the leafhopper belt. Carter's own experimental work is sufficient proof of the impossibility of his claims of three generations in Idaho. He quotes Haegele and Knowlton as proof of his contentions, but there is no evidence that either one ever bred a leafhopper. Haegele based his statements on "collections", a method which is almost certain to lead to erroneous conclusions in the hands of an amateur. Knowlton, not to be outdone, has recently announced four generations in Utah, without any apparent evidence that there is more than one.

ARE THERE DARK OVERWINTERING AND LIGHT SUMMER FORMS OF THE BEET LEAFHOPPER?—We now come to the most puzzling and confusing part of the whole discussion. In most phases of the problem, it has been possible to go back to definite experimental results and clear up the situation, but in this particular case, we appear to have a mass of assumptions and assertions, and erroneous conclusions based on these assumptions and assertions. It took the writer a long while to obtain any concept of what they were attempting to interpret because there is no parallel nor anything remotely comparable in our whole knowledge of leafhopper life histories. It is possible that the writer does not yet understand, for the statements are vague, confusing and contradictory in the extreme, but apparently the assumption is made that there is, occasionally, a special dark colored overwintering form produced during the latter part of the summer, which is different from the remainder of the progeny; that, later in the season, still more of these forms are produced; and that late in the fall all of them are of this type. This form is assumed to go over winter without developing eggs while, conversely, light summer forms produced at the same time are supposed to mature eggs in a short time and continue the reproductive process. There is no parallel for this state of affairs known in the leafhopper group.

This would be harmless in itself, simply an additional contribution to our "*tiddle-dy-winks*" type of amusement, if it were not for the fact that it has been used as a basis for an assumption that all pale forms are

products of the summer generations, capable of almost immediate propagation and, therefore, when pale forms are found in the spring, the assumption is immediately made that they have developed during that season.

Going back to our knowledge of other forms of leafhopper, we find that the production of dark colored forms is a common and well known phenomenon that has been definitely correlated with their development in cold damp situations while, on the other hand, extremely pale forms are the products of the dry deserts. This has nothing to do with the perpetuation of the species in any way, and it may occur at any time in the season when conditions are favorable. *Cicadula sexnotata*, the leafhopper which carries the aster yellows, exhibits this character even more definitely than the beet leafhopper. Examples developed at any season of the year in damp mountain meadows are likely to be extremely dark while those developing under hot arid conditions will be almost colorless.

Turning back to the beet leafhopper, one can see how such an assumption would arise, especially if the workers were located within the fog belt, as most of them have been. With the precipitation coming in the winter time, those leafhoppers produced late in the summer and in the fall will naturally be dark colored, but this may not apply at all to insects produced in the hot and dry desert regions at the same period, and when such an assumption is transferred to Arizona where the wet season is in the hottest period of the summer, it becomes absurd. This same assumption has been taken up by the workers in the intermountain region and they have talked learnedly of "dark colored winter forms" and "light summer forms" when they are dealing with a single generation condition and a very different climatic complex.

Carter states definitely that, in his cage experiments in Idaho, he never produced anything but dark forms when the temperatures were low and the moisture high, regardless of the season. On the other hand, the years of extreme abundance in the Utah region have also been exceptionally hot and dry, and almost the entire progeny produced under such conditions are extremely pale (hence the name *white fly*).

We must, therefore, conclude that dark forms and pale forms have nothing to do with generations, and cannot be used for such determinations. This does not mean that there may not be conditions in which overwintering forms will be largely dark but, conversely, there may be other regions in which the overwintering forms are all light.

Changes in Color at Mating Season.—The grape leafhopper and its allies, have life histories very similar to those of the beet leafhopper, that is, they produce a single generation in the northern regions and an

almost complete second generation in Southern California. These leafhoppers, of which there are many species, are disgustingly drab and undifferentiable in the winter period but when mating time comes in the spring, they change to bright hues and brilliant stripes and markings and are easily separated. It may well be that the beet leafhopper undergoes a corresponding change in the spring period and that many of the so-called dark overwintering forms become light spring forms at the mating season, and this raises another question.

Do the Migratory Forms Mate in the Fall or in the Spring? —The leafhoppers which hibernate as adults and migrate to their food plants in definite swarms in the spring, such as the grape leafhopper, and the potato leafhopper, do not become sexually mature until late in the spring, and the mating process usually takes place in connection with the spring flight. In the case of the beet leafhopper, the testimony is very conflicting, probably because of the fact that there are mixed populations, as will be later discussed.

The writer's observations in Utah indicate that the males appear in the beet fields with the females and that egg laying does not begin for a number of days. Other workers have recorded flights of leafhoppers which were all females, ready to lay eggs upon arrival. It is very probable that both of these observations are correct, since hibernating populations may be made up of the very diverse material, depending upon the character and length of the previous season. For example, let us take the situation in Utah: The great majority of the beet fields in this state are at elevations of approximately 5000 feet, or above, and the season is relatively short. Under these conditions, the beet leafhopper scarcely has time to produce a single generation and there has been no development of eggs or mating in the fall observed. These leafhoppers disappear out of the fields early in the fall, some time before the harvesting of the sugar beets, and reappear in a definite flight the last of May or, usually, early in June. This is exactly what happens in the case of the grape leafhoppers and the potato leafhoppers, and there is no inference on the part of any one that either of these insects produce a generation in the period of absence. Under Utah conditions, the males and females are proportional in numbers, although it is a fact that, in using a sweepnet, more of the heavy bodied females will be caught than the light males. There does not seem to the writer any excuse for conjuring up a brood in the desert, or the development of a generation on sunshiny days in the winter, or any other fantastic theory, when everything which occurs is logically explainable by the normal responses of the leafhopper group.

On the other hand, Stahl and Severen's careful experimental work has shown conclusively that, in California under the proper stimulus of young food plants, the beet leafhopper does continue to reproduce exactly in the same way as the grape leafhopper has been shown by Quayle to develop two generations in Southern California, the second being rarely completed. While the writer still believes that there is ordinarily but a single long drawn out generation *on the sugar beets*, even in California and Arizona, he does recognize that, in Arizona and the warmer desert regions of California, there is probably a two-generation development, with a more or less quiescent period of aestivation in the heat of the summer, and dormancy in the winter.

Between these two extremes, undoubtedly there is a gradation from a single-brooded condition through a very small partial second brood, up to a fairly complete two-brooded condition, and that this will undoubtedly vary from year to year, depending largely upon the character of the season, the rainfall, and especially upon the development of vegetation in the desert regions. Stahl records carrying a female leafhopper 19 months, and there are many records of survivals for more than a year. There must be an immense number of places in the desert regions where food plants dry up during the summer period long before the females have completed their egg laying. These females may readily aestivate, and begin laying again when vegetation is available; this has been observed in a number of cases. In the same way, females stimulated to egg production in the fall of the year by feeding on fresh young vegetation, may hibernate after laying a small number of eggs. Frequently, they will be caught in a cold snap with fully developed eggs in the abdomen, and these will remain quiescent throughout the winter. Along with these, there will be females of the latter part of the first generation who have not laid out more than half of their total possible egg production when the temperature dropped so low that egg production ceased. We may, therefore, have going over winter side by side, females of the first brood that have not been stimulated by fresh vegetation and therefore have not developed sexually; females of the second generation who normally would go over winter without sexual development; females of the latter end of the first generation that have not completed egg laying; and females of the second generation that were stimulated by fresh vegetation to beginning reproduction at the end of the season and who still carry nearly their full quota of eggs. To add to the complexity, under favorable conditions the larger nymphs may be enabled to hibernate successfully and they would appear as adults in the early spring.

With this complex assortment of egg laying potentialities, is it any wonder that the observer in the field has become confused, and has gone to wild extremes in theories and assumptions?

The females that have once started to lay eggs in the previous season will resume egg laying as soon as the temperatures are favorable. On the other hand, those that have not developed eggs in the fall usually have a considerably longer pre-oviposition period, often ending in a concerted migratory flight and a mating period.

WHAT CAUSES FLIGHTS?—In the case of the grape leafhopper and the potato leafhopper, both of which come out of hibernation a month or six weeks before their spring flight and before their respective host plants have developed leaves, the spring flight is usually made on a warm, quiet and humid afternoon, and embraces the entire number of insects in the region. This is established by the fact that potato plants which are not up on this particular date are often not infested until the summer flight of the next generation takes place. These insects have been feeding on the miscellaneous assortment of spring vegetation but, irrespective of the host, they all join in the spring migration. Is it not possible to conceive of the spring migration of the beet leafhoppers occurring in exactly the same way, even without any factor of the drying up of the desert vegetation? There is, of course, no suggestion of the vegetation drying up in the case of the potato or grape leafhoppers, as that is the time of the most luxuriant growth of the year, and the writer has observed exceedingly luxuriant growths in the Escalante Desert, even after the period of the spring migration of beet leafhoppers into Utah. In the case of the potato leafhoppers at Ames, Iowa, the second generation is rarely completed when cold weather kills the potatoes. As a result, some of the females of the first brood that had not completed their egg laying are forced to hibernate and have been observed to begin depositing eggs within a week or two after they appeared in the spring. As there would be no potatoes available at this time, these eggs are deposited on dock or sweet clover, or similarly early developing vegetation. It has never been possible to tell whether these females took part in the migration or not, but apparently they did as the production of nymphs on this vegetation did not continue after the flight. However, this may have been due to the completion of the egg laying period.

In the case of the beet leafhopper, it is possible that the females that had already mated and begun to lay in the fall of the year would not have the sexual urge, which has been interpreted as the basis of the spring migrations, and that they would remain on the desert vegetation as long as it was succulent. On the other hand, there are many immense

populations of the beet leafhopper on filaree which normally dries up at a very early period. These hoppers, irrespective of mating instincts would be compelled to migrate.

Therefore, we might have migrations composed entirely of fresh males and females just becoming sexually mature. We might also have forced migrations from drying vegetation, which would include both fresh adults and those that had been laying the previous season. It is also possible that the freshly maturing individuals would migrate at the normal migratory time, and that this migration would be made up of both sexes, in approximately equal numbers, and that later on, due to drying of the vegetation, the females that had been laying the previous year would be forced to migrate, and we would then have a late migration made up entirely of females that were all in laying conditions and would produce eggs immediately.

Taken all in all, it should be evident by this time that this is an exceedingly complicated biological problem of multifarius ramifications and that there are many extremely important factors which have not yet been determined, and that we need careful and accurately controlled experimental work along these lines rather than assumptions and loose statements.

We should remember also that this is primarily an economic problem and what we are seeking is information which will assist in the elimination of this serious and, in many places, fatal hazard to the normal development of a great industry. While we must carry on experiments under artificial and controlled conditions for the purpose of obtaining accurate results, the conclusions obtained should not be heralded as applying to conditions in the sugar beet fields.

REPORT ON ALFALFA WEEVIL INVESTIGATION IN CALIFORNIA

By A. E. MICHELBACHER and E. O. ESSIG, *University of California, Berkeley*

Since the discovery of the alfalfa weevil in middle California on May 12, 1932 its spread has been very slow. In some places there has been little or no extension of the infested area. From available data it appears to have spread most rapidly on the west side of the San Joaquin Valley. Here it has recently been found three miles west of Gustine, which is equivalent to an air line advance of about 5 and ½ miles. Elsewhere the boundary is much the same as in 1932. It is hard to explain why the weevil has not spread more rapidly and to greater distances. If its dispersion was slow only in the San Joaquin Valley one might attribute it to the hot, dry climate that prevails there. However, its spread has also been slow in the cooler San Francisco Bay Region, which would indicate that factors other than climate must be involved. Host abundance, wind movements, and perhaps other elements, may have a very important bearing. Some of these factors have been discussed in a previous paper entitled: "A progress report on the behavior of the alfalfa weevil in middle California;" to appear in the JOURNAL OF ECONOMIC ENTOMOLOGY.

In the investigation of this pest our main endeavor has been to determine, in so far as possible, the conditions which limit its destructiveness. Important among these are: climate, natural enemies, frequency of cutting, age and character of stand, irrigation, cultivation, and the general care which a field receives.

Of all the factors concerned those pertaining to climate seem to be the most important. This is particularly true of the San Joaquin Valley, where the weevil population has remained small. The highest average number of weevil larvae collected to the 100 sweeps of an insect net in any one field was 1,198. In other fields peak counts for the most part were 200 or less, with some fields showing counts of less than 50. The highest population could have been materially reduced by timely cutting. Even where the density of larvae was greatest, injury was slight, and was mainly confined to the edge in the particular field most carefully studied. In general it can be said that weevil injury in the San Joaquin Valley has not been noticeable, and if conditions continue in the future as they have in the past, it will not prove to be a major pest.

Some injury of a serious nature occurred in several fields in the Pleasanton and Niles areas. The climate of these two places is somewhat different, that about Niles being cooler in summer and warmer in winter due to the moderating influence of the San Francisco Bay. In these

places an opportunity was afforded to study the factors which apparently influence the injury that is likely to occur. From observations it seems that the climate of the Niles region is more favorable for weevil development than that of Pleasanton. The more moderate climate probably allows the brood to extend over a long period of time and this, of course, results in the larvae being present in fair numbers during most of the year, particularly during the growing season. It is possible that there are adults reaching sexual maturity at different times during most of the year. At present we are conducting an investigation which we hope will give some information on this subject, and which will also show whether or not there is a sizeable second brood. It is our belief that a fairly large second brood occurs, as is evidenced by the fact that two quite high larval peaks are reached: one about the end of March, and the other around July. This was clearly shown in our 1933 season's work, and it is expected that the same thing will occur this season.

The fact that the alfalfa weevil damage in middle California is not as serious as might be expected can probably be explained to some extent by the rapid growth of the alfalfa in the spring. We have not had an opportunity to observe alfalfa growth elsewhere, but judging from a single trip into the Honey Lake Region of northeastern California (4,000 feet altitude), the response of alfalfa to favorable growing conditions is greater in lowland portions of the state than it is there. It seems that anything which will invigorate the alfalfa and stimulate its growth will tend to reduce weevil injury. In this regard the frequency of cutting will first be discussed. The danger of cutting alfalfa too frequently has been well demonstrated in the Niles territory. On certain ranches in this section there has been a tendency to cut the fields at such short intervals that the vigor of the alfalfa is greatly reduced. Even though other growing conditions are favorable, under such circumstances the alfalfa makes slow growth. If such fields are infested with the alfalfa weevil, serious injury may result before the alfalfa is ready to be harvested. In like cases, but where the alfalfa is able to make a vigorous growth, it is almost certain that the field could be cut before the injury became truly serious.

The reduction of stand is another factor which seems to favor injury. Usually after four or more years a greatly reduced stand is likely to occur. Alfalfa plants in such fields do not seem to respond quite as rapidly to favorable growing conditions as do younger plants. Also in such cases the number of weevils per plant is greater than where there is a thick, even, uniform, stand. This greater concentration of weevils together with apparently slower growth, makes injury more noticeable.

Such conditions were observed in the Pleasanton region this past spring and to a lesser extent in the country about Niles.

The value of young, vigorous stands was clearly demonstrated in the territory about Pleasanton during the past winter and spring. Here second year alfalfa was ready to cut when older fields in the district were only one-half to two-thirds grown. So rapid was the growth in these fields that the larval population amounted to almost nothing at the cutting of the first crop. This was in marked contrast to the populations found later in the slower growing fields.

The time of cutting of the first crop certainly has a direct bearing on the amount of damage caused by the weevil. In almost every case where serious injury occurred, most of it could have been avoided by timely cutting. There are numerous cases where the alfalfa was allowed to go ten days to two weeks beyond the time it could normally have been cut, and it was during this period that the most of the damage was done. In nearly every one of these fields the larval population showed a marked increase in numbers after the alfalfa was ready to cut. This peak was followed, as a rule, by a decided decline before harvest. Table 1 has been prepared to show the population trends in such fields.

TABLE 1. POPULATION TRENDS DURING GROWTH OF FIRST CROP

Location	Date of observation	Stage of growth 1st crop	Aver. no. of larvae collected per 100 sweeps of an insect net	Aver. no. of adults collected per 100 sweeps of an insect net	Date field was cut	Age of field (years)	Care which field received
*Centerville	1-17-34	—	24	2		4 or 5	Fair
*Centerville	1-25-34	—	38	3			
*Centerville	2-9-34	¼	100	4			
*Centerville	2-28-34	⅓	198	17			
*Centerville	3-6-34	½	245	18			
*Centerville	3-14-35	⅔	586	15			
*Centerville	3-23-34	⅞	699	9			
*Centerville	3-30-34	Mature	794	15			
*Centerville	4-5-34		1048	50	4-8-34		
*Niles.....	1-17-34	—	25	0			Poor
*Niles.....	2-28-34	½	319	24			
*Niles.....	3-14-34	⅞	557	15			
*Niles.....	3-21-34	Mature	755	5			
*Niles.....	3-30-34		1801	26			
*Niles.....	4-5-34		1541	103	4-11-34		
*Irvington..	2-9-34	⅓	6	1		4	Good
*Irvington..	3-6-34	¾	22	3			
*Irvington..	3-23-34	Mature	50	1	4-1-34		

*Niles Territory (San Francisco Bay Region).

TABLE 1—*Concluded*

Location	Date of observation	Stage of growth 1st crop	Aver. no. of larvae collected per 100 sweeps of an insect net	Aver. no. of adults collected per 100 sweeps of an insect net	Date field was cut	Age of field (years)	Care which field received
Pleasanton.	3-6-34	1/3	177	12		4	Fair
Pleasanton.	3-15-34	1/2	321	5			
Pleasanton.	3-29-34	Mature	604	1			
Pleasanton.	4-5-34		1087	18			
Pleasanton.	4-11-34		663	20	4-14-34		
Pleasanton.	1-17-34	—	2	0		6	Fair
Pleasanton.	3-6-34	1/3	71	12			
Pleasanton.	3-15-34	2/3	188	6			
Pleasanton.	3-29-34	Mature	735	5			
Pleasanton.	4-5-34		1036	8	4-14-34		
Pleasanton.	4-11-34		692	14			
Pleasanton.	3-6-34	1/4	106	8			Poor
Pleasanton.	3-15-34	1/3	516	17			
Pleasanton.	3-23-34	2/3	1121	8			
Pleasanton.	3-29-34	Mature	1977	10			
Pleasanton.	4-5-34		4187	8			
Pleasanton.	4-9-34		3202	26	4-11-34		
Pleasanton.	2-12-34	1/4	3	1		2	Good
Pleasanton.	3-6-34	2/3	12	2			
Pleasanton.	3-15-34	Mature	67	6	3-20-34		
Pleasanton.	2-12-34	1/4	5	1		2	Good
Pleasanton.	3-6-34	2/3	107	9			
Pleasanton.	3-15-34	Mature	142	3			
Pleasanton.	3-23-34		291	2	3-23-34		
†Tracy.....	2-12-34	1/4	0	1		2	Fair
†Tracy.....	3-5-34	1/2	10	12			
†Tracy.....	3-12-34	3/4	25	10	3-15-34		
†Tracy.....	2-12-34	1/8	0	0			Fair
†Tracy.....	3-5-34	1/2	16	4			
†Tracy.....	3-12-34	3/4	36	6			
†Tracy.....	3-20-34	Mature	214	7			
†Tracy.....	3-5-34	1/2	7	0		3	Good
†Tracy.....	3-12-34	7/8	18	1			
†Tracy.....	3-20-34	Mature	35	1	3-20-34		
†Vernalis....	2-12-34	1/4	8	7		5	Poor to Fair
†Vernalis....	3-5-34	1/2	172	18			
†Vernalis....	3-12-34	3/4	345	17			
†Vernalis....	3-20-34	Mature	1198	5			
†Vernalis....	3-29-34		362	0	3-30-34		
†Vernalis....	2-12-34	1/4	1	1		5	Fair
†Vernalis....	3-5-34	1/2	13	2			
†Vernalis....	3-12-34	3/4	29	4			
†Vernalis....	3-20-34	Mature	140	0			
†Vernalis....	3-29-34		30	0			
†Vernalis....	4-9-34		15	6	4-9-34		

†Tracy Territory (San Joaquin Valley).

‡Net used in making sweeps, No. 5 "Harrimac" landing net. Collapsing steel frame, Richardson Rod and Reel Co., Chicago.

The dryness of the past winter and spring served to complicate matters somewhat. In many places there was barely enough rainfall to produce a satisfactory first crop. In such places, if the alfalfa was not cut when ready, it became very dry. There was a drying up of the lower leaves and in some cases even the tops showed the effect of drought, and this condition served to accentuate weevil damage.

There are at least three reasons which may account for delayed cutting of the first crop. Where holdings are large and the entire crop has a tendency to mature simultaneously, it becomes difficult to harvest the whole acreage just at the proper time. Also, during the cutting of the first crop weather conditions may not be favorable for haying, and this may prolong harvest. The depressed economic situation also has played a part in this connection. There are cases where farmers are unable to hire extra help during the haying period; and this delay may result in serious weevil injury to the alfalfa before it is cut.

Not only does the delayed harvesting of the first crop increase the danger of weevil injury, but it also allows ample time for many larvae to complete their development, pupate, and emerge as adults. This condition seems to permit a carryover of a rather large adult population with the result that weevil injury the following year is more likely to occur. This seems to be shown in the Pleasanton territory where the area of heaviest infestation more or less coincides with the region where the fields have been most neglected.

The exact extent of adult weevil dispersal from one field to another has not been determined. That considerable movement takes place is demonstrated in the Pleasanton area, where weevils have been collected with some ease in alfalfa fields during their first season of growth. Evidence also seems to indicate that there may be some transfer of the weevils from neglected fields to those which are better cared for. At present during the second year, there is one area in which large adult populations were allowed to build up due to delayed cutting of the first crop, and the fields were thereafter neglected. That is, no irrigation was given, and the fields literally dried up. Under such conditions it is certain that many of the adults leave such dry environments and find their way into the nearby better cared for fields. This is indicated by the fact that nearby fields usually show higher populations than fields located some distance away.

After the removal of the first crop, several weeks are often allowed to pass before the fields are irrigated. During the past spring in most cases where this occurred the alfalfa failed to make any appreciable growth, due to lack of winter rains, until water was applied. Under such condi-

tions some very slight injury to the developing buds and young shoots was observed. This loss could have been reduced to almost nothing had the fields been irrigated a few days after the removal of the hay. Enough time would have been allowed for climatic and culture kill and alfalfa growth would have been stimulated to a point where any injury that might have occurred would have been hardly noticeable.

Winter cultivation has been recommended to stimulate the growth of alfalfa, and thus reduce injury. Observations have borne this out. However, if fields are cultivated it appears best that this work should be done early in the winter before weather conditions become favorable for the growth of the alfalfa. If done too late it may retard growth somewhat, and as rapid maturity of the first crop is much desired, such a practice should be avoided.

In general, through the entire range of the weevil in middle California little damage has been done. Here and there it has proved to be rather injurious, but in practically every case the injury could have been reduced if better farm practices had been followed. In most instances it seems that there were barely enough adults present in the fields to produce sufficient larvae to do serious damage. This would indicate that only under unusually favorable conditions is the alfalfa weevil able to do much injury. Our investigation to date has led us to believe that this pest can be held in check without resorting to poisonous sprays or dusts. However, experimental work along this line will be conducted if the weevil becomes too destructive in localized areas. To the present time this line of investigation has not been attempted, as it appears that such work will be unnecessary if the growers improve the cultural care. Most of the farmers have been indifferent to any damage done by the weevil, and as long as this attitude is maintained chemical control is superfluous.

There is no doubt but that there are numerous natural enemies of the weevil that tend to restrict its numbers. At present these include birds, predacious insects, other insectivorous animals, and probably fungous diseases. Attempts are being made by the United States Department of Agriculture, Bureau of Entomology, alone, and in cooperation with the University of California Experiment Station to introduce parasites of the weevil into the infested area. Establishment of these parasites, if successful, may become an important factor in the control of the weevil. To the present time *Bathyplectes curculionis* (Thomson) appears to be the only parasite established for a certainty.

In general, populations encountered on the first crop were greater this year than last. This probably was the result of the extremely mild fall and winter, which occurred throughout the entire infested area.

In conclusion we wish again to state that factors other than climate tend to limit the destructiveness of this serious alfalfa pest. These are proper winter culture, timely cutting, avoiding too frequent cuttings, maintaining a good stand, encouraging natural enemies, and, when the soil moisture is low, irrigating the field soon after the crop is moved. If these farm practices are followed, it is certain that injury by the alfalfa weevil can be reduced materially.

ANARHOPUS SYDNEYENSIS TIMB., AN ENCYRTID PARASITE OF PSEUDOCOCCUS LONGISPINUS (TARG.) RECENTLY INTRODUCED INTO CALIFORNIA FROM AUSTRALIA[1]

By HAROLD COMPERE and STANLEY E. FLANDERS, *Research Associates in Entomology, University of California, Citrus Experiment Station*

Anarhopus sydneyensis Timberlake was introduced into California by the Citrus Experiment Station of the University of California in an attempt to control an outbreak of the long-tailed mealybug, *Pseudococcus longispinus* (Targ.). This mealybug has been present in California for many years, but prior to 1933 it has not been abundant enough on citrus to be considered as a pest. During the summer of 1933, an injurious infestation of *P. longispinus* developed on orange trees near Downey in southern California. The infested area extended over 200 acres, and the situation was such as to require control measures. In August, 1933, S. E. Flanders entered into correspondence with L. Gallard, of Sydney, Australia, for the purpose of securing Australian parasites of *P. longispinus* to control the infestation at Downey.

While in Australia, in 1931, on another project, Flanders reared *Anarhopus sydneyensis* Timb., *Anagyrus nigricornis* Timb., and *Ophelosia crawfordi* Riley from *Pseudococcus longispinus*. L. Gallard, of Sydney, assisted Flanders in collecting samples of the various species of mealybugs for the purpose of rearing their parasites. During the latter part of March, 1931, Gallard collected parasitized *P. longispinus* on quince trees at the Lovell Place, Eastwood, New South Wales. Flanders reported that these mealybugs were highly parasitized by *A. sydneyensis*. Subsequently several shipments of parasitized mealybugs were sent to Riverside. These produced numerous *Ophelosia crawfordi* and comparatively few *Anarhopus sydneyensis*. The chief concern was regarding

[1]Paper No. 301, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

Ophelosia, which readily reproduced and became very abundant by feeding on the eggs of several species of California mealybugs. When propagating on unparasitized mealybugs, *Ophelosia* develops as a predator, the larvae feeding upon mealybug eggs and young, and in this role the species is beneficial. It was also discovered that *Ophelosia* frequently developed as a hyperparasite at the expense of primary internal parasites of mealybugs. In some samples received from Australia, *Ophelosia* almost completely destroyed and replaced the primary internal parasites. Because of the hyperparasitic habits of *Ophelosia*, it was considered inadvisable to colonize the species in California. Smith and Compere briefly reported on the importation of *Ophelosia crawfordi*[2] and concluded by stating:

"In view of the very satisfactory mealybug situation in California, and the impossibility of determining in advance what the final results of the establishment of *Ophelosia* would prove to be, the colonies of *Ophelosia* have been destroyed without making any liberations."

The *Anarhopus* which issued from the Australian mealybugs in 1931, were confined in cages and jars with *Pseudococcus maritimus* Ehrh., *Pseudococcus gahani* Green, *Pseudococcus citri* (Risso), and *Phenacoccus gossypii* (Towns. and Ckll.). Although the parasites were seen to oviposit no reproduction was obtained. At this time, 1931, *Pseudococcus longispinus* was not considered of economic importance, and no special effort was made to propagate *Anarhopus* upon it.

The outbreak of *Pseudococcus longispinus* at Downey, in 1933, made it advisable to attempt again the introduction and establishment of *Anarhopus* on this host. The knowledge regarding Australian parasites of *P. longispinus*, which Flanders obtained in 1931, and the connections established there, made it possible to attempt the importation of parasites immediately following the outbreak in California.

On August 8, 1933, a letter was sent to L. Gallard, requesting a shipment of parasitized mealybugs from the quince trees at Eastwood. In October, Gallard sent the first shipment, which did not appear very promising because the material was rather old; so it was agreed to send a second shipment on the next steamer. The first shipment, received November 4, 1933, consisted of over 100 mummified mealybugs. The parasites had issued from most of these mealybugs before they were collected, and except for 5 female *Anarhopus*, the others died en route. One female *Anarhopus*, which was an adult when the box was opened, was allowed to oviposit in *Pseudococcus longispinus* from November 5

[2]Jour. Econ. Ent. 24:1109–1110, 1931.

to 7th. She was then isolated in cold storage and every 3 or 4 days was taken out and fed on honey. The mealybugs that were parasitized by this female on November 5 and 6th mummified on November 18 and 19th; and on December 4, male *Anarhopus* began to issue. A total of 12 male *Anarhopus* was obtained as the progeny of the one female. She was then removed from cold storage and mated with her offspring. The

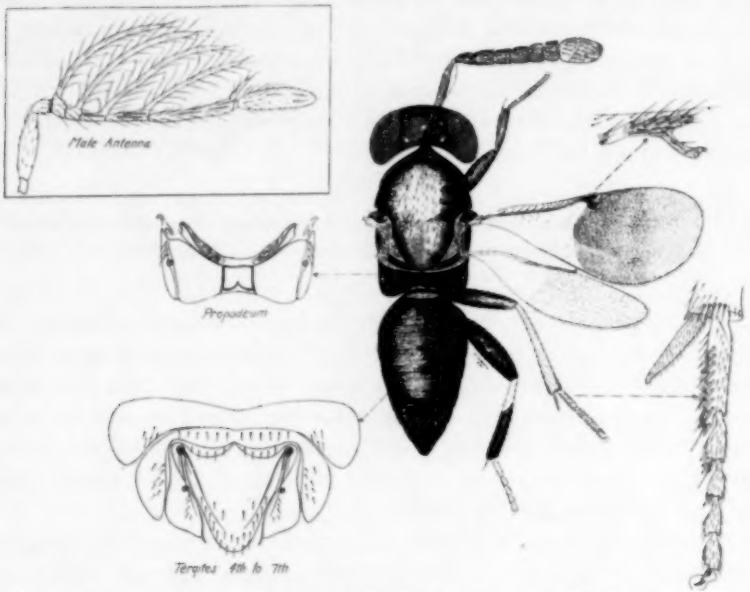

FIG. 103.—*Anarhopus sydneyensis* Timb. Female with detail of parts, and male antenna.

second shipment, which was received on December 2, 1933, consisted of 16 mummified mealybugs, of which 8 were in good condition. The mummies yielded 6 female and 1 male *Anarhopus*. As the females emerged, they were mated and released in cages containing *P. longispinus* growing on potato sprouts. From the mated females, progeny of both sexes were obtained. These began issuing January 1, 1934.

The first field colonization was made March 6, 1934, when adults were liberated on orange trees infested with *Pseudococcus longispinus* in the Las Dos Palmas grove at Downey. On the same date a small colony of *Anarhopus* was given to the Los Angeles County insectary so that this organization could assist in the propagation and distribution of the parasite.

This encyrtid was described by P. H. Timberlake, in 1929, as the sole species of the new genus *Anarhopus*. The type material comprised four females collected near Sydney, Australia, by H. Compere in December, 1927. Three of the type specimens were reared from mealybug mummies collected on a citrus tree at Warrawee, and the other specimen was captured as an adult on the limb of an orange tree at Wahroonga.

The genus *Anarhopus* is related to *Tetracnemus* Westwood and *Arhopoideus* Girault.

Timberlake has adequately described the female of *Anarhopus sydneyensis* in the taxonomic paper cited. The following abridged description and the figure may assist in the recognition of the species.

Anarhopus sydneyensis Timberlake

Anarhopus sydneyensis Timberlake, Univ. Calif. Publ. Entom. 5 (2):15, 1929.

Female.—General color dark metallic with reflections, the mesoscutum almost green in some lights, the scutellum less refringent than the mesoscutum because of the coarser sculpture. Basal part of the abdomen with bluish-green reflections. Hind legs black except the basal half of the tibiae which are white in sharp contrast. Middle legs with the tibiae white and the femora brown, except for a white ring at base. Scape mostly white; the flagellum black. Fore wings infuscated from the costal to the posterior margin and extending from the stigmal vein toward the apex, the apex of the wing hyaline or nearly so. Flagellum slightly compressed. Abdomen slender. Basal part of fore and hind wings clear with few transparent refractive cilia. When the wings are at rest, longitudinally overlapping the body, the refractive cilia appear as a transverse whitish band against the dark background. Legs strongly developed.

Male.—A detailed description of the male has not been prepared. In regard to stature, sculpture, and coloration, the male of the species is similar to *Tetracnemus pretiosus* Timberlake. In California there are two species of encyrtids in which males have branched antennae. In *T. pretiosus* the antenna has four branches, while in *Anarhopus sydneyensis* the apex of the fifth funicle joint bears a short ramus or vestigial fifth branch and the proportions of the joints are different, as can be seen by a comparison of the male antenna shown in Figure 103 with that of *T. pretiosus* as illustrated by Timberlake in his description of the latter.

OVIPOSITION.—*Anarhopus* oviposits in mealybugs of all sizes. Attempts to oviposit in very small individuals are often unsuccessful, for, instead of piercing the mealybug, the ovipositor dislodges or entirely misses the intended victim. When mealybugs of various sizes are provided and the parasites allowed to take their choice, the medium to large-sized specimens are selected. Although *Anarhopus* can be induced to oviposit in *Pseudococcus citri* (Risso), *P. maritimus* Ehrh., *P. gahani* Green, and *Phenacoccus gossypii* Towns. and Ckll., it shows a marked preference for *P. longispinus*. Only rarely can *Anarhopus* be induced to oviposit in *P. gahani* unless that species of mealybug is smeared with the

body fluids of *P. longispinus*. The stimulus to oviposition is provided by mealybugs, their excrement, secretions, eggs or body fluids. *Anarhopus* will attempt to oviposit in smears of body juices on glass or paper. The attempts to oviposit in unsuitable objects usually cease after the parasite makes a few unsuccessful thrusts with its ovipositor.

Oviposition is quickly accomplished when the parasites attack a suitable host fixed to a plant and thrust the ovipositor accurately. After making a brief antennal inspection of the host, *Anarhopus* moves to one side, headed away from the host, and extrudes the abdomen and ovipositor in a quick backward movement. In this movement the distal ventrites are extended, causing the abdomen to elongate to almost twice its

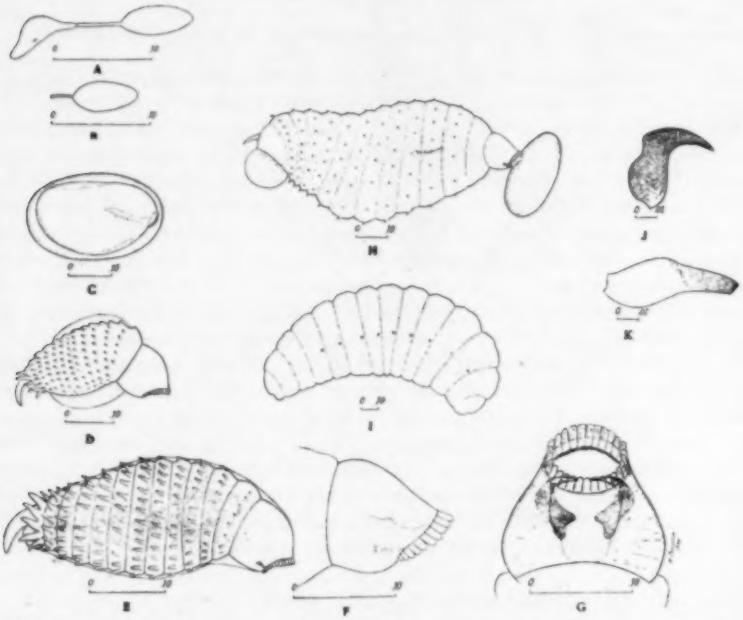

FIG. 104.—*Anarhopus sydneyensis* Timberlake. A, Ovarian egg; B, newly deposited egg; C, embryo, sixth day, found with another embryo and two larvae in one host; D, larva, sixth day, one of two larvae found with the two embryos in the same host; E, larva, eighth day, showing cuticular processes and enveloping membrane; F, head, eighth day larva, side view; G, head, eighth day larva, ventral view; H, larva, fourteenth day, eating mealybug egg, anal vesicle fully developed and larva about ready to moult; I, larva sixteenth day, second instar, about full fed and ready to pupate; J, mandible of first instar larva; K, mandible of second instar larva.

The scale, in millimeters, is given beneath each figure.

relaxed size. The naked ovipositor issues horizontally from the apex of the extended abdomen and is inserted a short way into the host through the ventral side near the margins. The parasite holds its wings erect and the abdomen and ovipositor extended for one or two seconds while the egg is being laid. After the egg is deposited, the abdomen relaxes, the extruded ventrites telescope beneath the distal tergites, and the ovipositor folds within the abdomen.

EGG.—Because of their small size and transparency, the eggs of *Anarhopus* are difficult to find after they have been deposited. Many examinations were made of mealybugs that were oviposited in by *Anarhopus*, without finding eggs. That oviposition actually occurred was shown by the finding of larvae in those left as checks and dissected at later dates. In a small percentage of the mealybugs examined, *Anarhopus* eggs were found in the drops of water in which the dissections were made. Figure 104B illustrates one of these eggs. It is possible that these free eggs were unknowingly detached from the body wall of the host. Repeated failures to find free eggs suggest the possibility that they are fixed to the integument of the host. Four specimens of what appeared to be *Anarhopus* eggs fixed to the integument of the host were found. Whether these were actually *Anarhopus* eggs, as suspected, or cells or glands of the host, was not determined. Various stains were used and several hundred mealybugs were examined without determining certainly just where the eggs of *Anarhopus* are deposited. The free eggs, as well as those that appeared to be fixed eggs, measured 0.08 mm. in length, exclusive of the short pedicel. The eggs are almost colorless and most easily seen against a dark background.

In a series of mealybugs, each oviposited in four or five times, one specimen contained 2 active *Anarhopus* larvae and 2 embryos, which issued with the mealybug fluids when the host was ruptured. One of the eggs with the embryo within is shown in Figure 104C, and one of the active larvae in Figure 104D.

FIRST-INSTAR LARVA.—The primary larvae of *Anarhopus* are very similar to those of *Tetracnemus pretiosus* Timb. Distinctive characters of both *Anarhopus* and *Tetracnemus* primary larvae are the cuticular processes, anal vesicle, and the large mouth with a rigid, circular, projecting rim. First stage larvae are inclosed in a tightly adhering, transparent membrane, presumably derived from the egg, which stretches as the larvae grows. The cuticular processes which girdle each segment, except the anal one, appear as thin, transparent, membranous outgrowths. The 13th or anal segment bears a single process which, except for its large size, is similar to those that encircle the segments. The anal vesicle is a

bladder-like sac which protrudes from beneath the last segment and gradually enlarges as growth takes place. The cuticular processes do not enlarge but become less and less prominent as the larvae increase in size. The anal vesicle is readily penetrated and stained by aceto-carmine. Within the vesicle the stain is taken up by the outermost palisade cells which partition the gut from the vesicle. The vesicle appears as a continuation of the hind gut when it is removed from a larva. The mandibles are large and strongly chitinized. Once or twice larvae have been observed with the mandibles grasping ovarian host eggs which had been punctured and partly consumed. In the late first-instar larvae rudimentary tracheae can be detected in the thoracic region, appearing as short trunks with vestigial branches.

When a mealybug is dissected, the *Anarhopus* larvae issue with the flow of escaping body fluids. When the cycle from egg to adult was 38 days, newly-hatched larvae appeared 6 or 7 days after the eggs were laid. These larvae were in the first instar about 9 days. The head and mandibles showed no marked changes throughout the stadium, although the body modifications were very pronounced.

Only 1 larva was found in a single host, except in the case already mentioned where 2 larvae and 2 embryos were found.

Second-Instar Larva.—In specimens of a lot that produced adults in 38 days, the first moult occurred about 15 or 16 days after the eggs were laid. Larvae of the second instar differ conspicuously from those of the first instar. After the moult, the cuticular processes, anal vesicle, hard head, acuminately pointed mandibles, and projecting chitinized, circular mouth parts disappear. Newly-moulted larvae are smooth, the head soft, the mandibles broad and finely serrated at the apex. There are 13 segments exclusive of the head. There are 9 pairs of spiracles located on segments 2 to 10. Except for the minutely serrated tips of the mandibles, the characters of second-instar larvae are quite similar to the generalized type of encyrtid larvae of the last stage. Full-grown larvae measured 1.7 mm. in length.

Up to the time of the first moult the larvae grew slowly, increasing from 0.35 mm. to 0.9 mm. in length and enlarging to almost thrice the original bulk. The mealybugs do not seem to be affected by the activity of the small, first-stage larvae. After the moult, the rate of growth is more rapid; in the lot which produced adults in 38 days, the larvae increased in length from 0.9 mm. on the 14th day to 1.4 mm. on the 16th day. Mealybugs showed visible signs of parasitism on the 16th day after the eggs were laid, when the parasitized specimens appeared inflated and rigid. Dissections made when the mealybugs first "mummified" revealed

full-fed larvae which still retained the meconia. Specimens of this lot cast the meconia on the 19th day. Adults issued April 3, from eggs deposited February 24, a period of 38 days from eggs to adults.

This information on the life history of *Anarhopus* was obtained from several lots of specimens grown in the laboratory. Medium to large-sized mealybugs were exposed to *Anarhopus* for oviposition. After the parasites oviposited, the mealybugs were isolated in gelatin capsules.

Anarhopus grown in the insectary, where the temperature ranges near 80° F. complete the cycle from egg to adult in about one month.

Mealybugs containing full-fed *Anarhopus* larvae, cleared and stained *in toto* without rupturing the integument, contained only two pairs of larval mandibles.

For some unknown reason, *Anarhopus* has not reproduced freely in the insectary, although always kept provided with an abundance of *Pseudococcus longispinus*. The third generation of *Anarhopus* grown in confinement in the insectary produced more than 20 males to each female, although the two sexes were present in about equal numbers when the females were ovipositing. In some cages there was no reproduction, and no cage produced anything like the number of *Anarhopus* that was expected.

Collecting Hydrophids with Pyrethrum Flower Dust. On August 1, 1932 while testing certain sprays and dusts at the Great Marshes, West Barnstable, Massachusetts, in company with Dr. H. J. Franklin and Mr. R. L. Armstrong, a noteworthy obervation was made. A saline pool, abounding with salt-marsh mosquito larvae (*Aedes sollicitans* Walker), was being dusted with a 10% pyrethrum-90% gypsum dust mixture when an adult hydrophid of the genus *Tropisternus* was seen just as it disappeared beneath the surface of the water. A grab for it failed to catch the beetle, and the usually satisfactory method for collecting hydrophids, namely, stirring the water vigorously and pulling up the vegetation, did not produce the insect. We moved on to other pools, but returned about fifteen minutes later. To my amazement there upon the surface of the water five or six paralyzed beetles of this genus were floating. Undoubtedly the pyrethrum dust mixture had captured them for me.

E. AVERY RICHMOND

PLATYNOTA STULTANA WLSM. (LEPIDOPTERA) DAMAGING GREEN ORANGES IN SOUTHERN CALIFORNIA

By E. A. McGregor, *Bureau of Entomology, U. S. Department of Agriculture*

Late in May 1933 the writer detected a small caterpillar (see Fig. 105) attacking green immature oranges in southern California, and has had the pest under observation since that time. Almost invariably the larva was observed operating in the space between the sepals and the base of the fruit and within loosely spun webbing. Its feeding consists of gnawing and rasping of the calyx and stem, but especially of the rind near the base of the orange (see Fig. 106). Less frequently the worms may feed on the sides of the orange or within the cavity at the navel end (of navel oranges). The typical damage consists of a ringlike series of scars around the stem end of the fruit. The writer has never observed this insect to cause lesions at all resembling the burrows of the orange tortrix. Quite often the disfiguration is sufficient to lower the grade of the orange. The adult, a small, warm-buff colored moth, was identified by August Busck (from reared material) as *Platynota stultana* Wlsm. (family Tortricidae).

FIG. 105.—Full grown larva of *Platynota stultana* greatly enlarged.

In 1920 R. S. Woglum reported[1] damage to citrus by this insect, identified at that time by Busck as *Platynota tinctana* Walker. Busck has since published the synonymy[2], which is as follows:

Platynota stultana Walsingham 1884.
Platynota tinctana Woglum nec Walker 1920.
Platynota chiquitana Barnes and Busck 1920.
Platynota tinctana Essig nec Walker 1926.

It is of interest to record that the damage to citrus by *Platynota* as noted by Woglum is very different from that observed recently by the writer. Woglum reared adults from burrows in ripe oranges, but the

[1]R. S. Woglum. A Recently Discovered Citrus Pest, *Platynota tinctana* (Walk.) in California. Monthly Bul. Calif. Dept. Agr., vol. 9, No. 8, pp. 341–343. 1920.
[2]Proc. Ent. Soc. Wash., vol. 35, pp. 191–192, 1933.

damage recorded by him consisted chiefly of the destruction of the tender leaves, especially in nurseries.

The injury to oranges by larvae of *P. stultana* bears a resemblance to the work of the citrus thrips, but, being caused by a chewing insect, the scars are deeper and more jagged than those of thrips. Persons not very familiar with the damage caused by the citrus thrips might easily mistake the injury by *P. stultana* for the ringlike scars at the stem end that are so typical of thrips feeding. The writer believes that the occasional reports of thrips damage in non-thrips districts probably have arisen from the confusingly similar work of *P. stultana*.

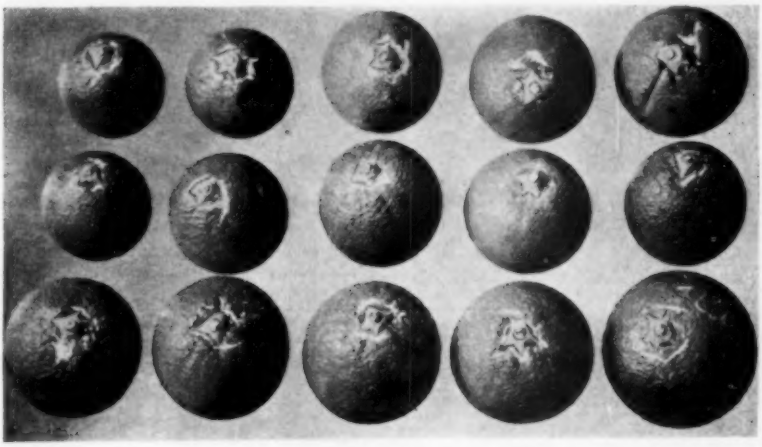

FIG. 106.—Young green oranges with rind injury near the stem end, caused by larvae of *Platynota stultana* Wlsm.

As the season advanced, a secondary type of damage, consisting of the dwarfing of the affected oranges, developed from the injury caused by this insect. As the fruits were approaching maturity, the writer observed numerous so-called "pee-wee" oranges in orchards where *P. stultana* had occurred. Almost invariably the scars caused by *Platynota* were present on these stunted oranges. Entomologists who have since observed this development are agreed with the writer that the dwarfing effect was caused by "calyx worms". The typical injury occurs so close to the point where the stem enters the fruit that it is probable that the flow of nutrient sap is impeded, with a resulting restricted growth of the orange. Figure 107 shows a series of these "pee-wee" fruits compared with a series of normal fruits, all taken from the same tree.

Since the stunted fruits are not all picked at harvest time, there is no

convenient way of making a direct count of normal and affected oranges. However, in three orchards in widely scattered districts the writer removed all the "pee-wees" from a few trees, and by counting them and

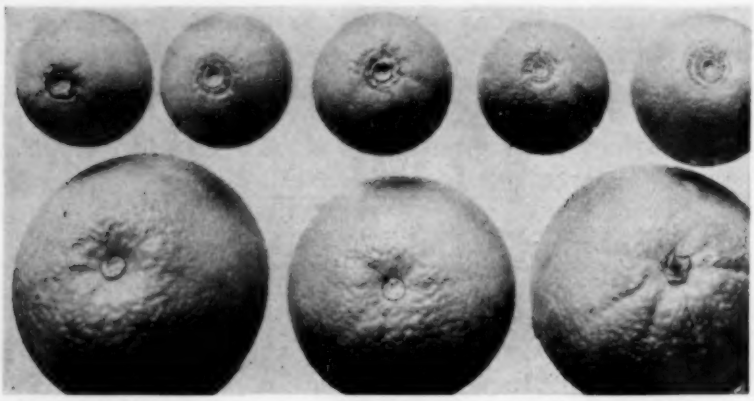

FIG. 107.—Three normal oranges and five "pee-wee" oranges picked from the same tree at the same time. Note the ring of scars made by larvae of *Platynota stultana* Wlsm. around the stem end of the stunted oranges.

estimating the total yield of normal oranges on these same trees, a fairly accurate estimate was made of the percentage of the total yield represented by the stunted fruits. The available data are presented in the following tabulation:

Orchard No.	Number of trees examined	Total stunted fruits	Av. stunted fruits per tree	Estimated total fruits per tree	Estimated per cent of stunted fruit
1.....	2	80	40.0	400	10.0
2.....	10	185	18.5	300	6.2
3.....	10	136	13.6	130	10.5

From these data it will be seen that in the three navel orchards in which counts were made of "pee-wee" oranges the computed loss ranged from 6.2 to 10.5 per cent of the crop. It should be added that a number of the dwarfed fruits had fallen to the ground prior to the time the counts were made and were not considered in the computations. The conclusion appears justified that in navel orchards affected by *Platynota stultana* commonly about 10 per cent of the crop is made unmarketable by the dwarfing effect of this insect.

The writer has studied this pest during a period of about 14 months, and the accumulated data justify the following summary of notations: (1) The insect (which in the citrus districts of California is spoken of as the "orange calyx worm") occurs very generally throughout southern

California, from Tustin to Redlands and Fillmore. (2) It has been found in 40 of the 42 orchards examined. (3) The degree of infestation of green oranges (as determined by inspection of 200 fruits taken at random in each orchard) was found to range from none to 72 per cent of the crop, the average for the orchards examined during 1933 being 25.6 per cent. (4) The pest occurs in greatest abundance in the San Gabriel Valley and at Arlington and Corona, and is least abundant in the eastern portion of the San Bernardino Valley. (5) A braconid parasite, *Apanteles aristoteliae* Vier., was identified by C. F. W. Muesebeck from specimens reared by the writer from larvae of *P. stultana*. (6) The initial injury consists of a ringlike series of scars on the fruit close to the stem; a secondary injury develops, consisting of the checking of the growth of some of the affected oranges, resulting in their becoming unmarketable. (7) The observations to date do not indicate that this insect will become of great economic importance.[3] Fully 25 per cent of the green oranges examined in a series of orchards in four counties in southern California bore the typical work of this worm, but a relatively small percentage of the crop was damaged sufficiently to lower the grade of the fruit.

Observations made in the affected districts during the summer of 1934, by other workers and by the present writer, have revealed that the tortricid worm, *Argyrotaenia citrana* Fernald, is also causing damage to green oranges quite similar to that of *Platynota*. In fact the work of the tortrix has exceeded that of *Platynota*.

[3]Since completing this paper some attention has been paid to the status of *Platynota* during 1934. It is evident that this insect occurs less commonly during the present year than was the case during 1933. However, a count made June 4, 1934, in an orchard at Corona revealed that about 96 per cent of the green oranges had been injured by this worm. The damage occurred during May. Preliminary control tests in the above locality have recently been made with the following: Two sprays and one dust, incorporating cryolite; one spray and one dust incorporating barium fluosilicate. All of these materials have given promising results against *Platynota* larvae. A dust combining one of these chemicals with sulfur, and applied during the period of thrips control, may prove satisfactory against both insects.

THE DOUBLE TREATMENT FOR SCALE PESTS IN CALIFORNIA CITRUS ORCHARDS

By R. S. WOGLUM and J. R. LAFOLLETTE, *California Fruit Growers Exchange, Los Angeles, Calif.*

The double or combination treatment of an oil spray and cyanid fumigation has proved of outstanding value in recent years in cleaning California citrus orchards of infestations of scale pests too severe to be controlled by a single application. The history of these treatments for the most part has been rather obscure even to most citrus entomologists. In the present paper an attempt is made to record the development of double or combination treatments in Southern California and to point out various factors which have influenced their use. This has been possible through the close field contact with citrus pest control maintained by the authors from the first application of miscible oils and white oils to citrus trees up to the present time.

Prior to 1920 fumigation was depended upon almost exclusively for the control of all citrus scale pests in Southern California. Occasionally orchards were sprayed with kerosene or distillates, either as tank-mix or home-made emulsions, but the amount was insignificant and the results generally unsatisfactory.

The extreme build-up of black scale following a heat wave in 1917 which had temporarily almost eliminated the pest, coupled with unsatisfactory fumigation control in Eastern Los Angeles County, led to the introduction at this time of various proprietary sprays, including miscible oil combined with lime sulfur, soapy distillate emulsions, arsenical combinations, and in 1923 of the first highly refined lubricating oil spray. During 1923, the failure of single applications of fumigation or spray to handle heavy black scale infestations lead, in many cases, to a repeated application of the same or some other material. Those used included combinations of fumigation with miscible oil and lime sulfur or highly refined white oil spray.

An analysis of the results of some 1500 acres of these combinations was made by the writers in the spring of 1924. These results showed that a double treatment of fumigation followed by a spray of miscible oil and lime sulfur was the most effective of the various combinations used against black scale and resulted in a generally uniform kill throughout the tree.[1] This effective combination was widely used for a few years, but has now given way to the white oil sprays. Thus it is seen that the first double or combination treatment for citrus scales was purely a field development from repeated efforts at control.

ontrol Circular 118, California Fruit Growers Exchange, 1924.

The first combination work toward red scale control was applied in the Whittier district in February, 1924, using various proportions of lime sulfur alone or miscible oil and lime sulfur, which was followed by fumigation at various intervals from 2 to 10 days. This combination treatment was applied to approximately 50 acres of lemons by the Murphy Oil Company, the Leffingwell Rancho, and the LaHabra Citrus Association. While these particular tests showed no significant superiority of the combination treatment over single fumigation, they did show that in fumigation alone the poorest kill was on the outside fruit, the difference being fully 10 per cent between the outside fruit adjacent the tent and the inside fruit away from the tent.[2]

The first combination treatment of white oil spray followed by fumigation was made during October-November, 1925, by the David Hewes Ranch at Orange. Similar combinations of oil followed within a few days by fumigation were made the same month by the Leffingwell Company and the LaHabra Citrus Association.[3]

The superior results evidenced by this oil-fumigation combination quickly led to its considerable commercial use, and during the first six months approximately 100 acres were combination treated. An analysis by the writers of all this early work showed an average kill of about 99 per cent. It was also brought out by the authors at this time that these two treatments were natural complements of each other.[2] Oil spray gave a decidedly superior kill on the fruit than on wood, whereas fumigation gave the best kill on the wood, outside fruit being poorest. This fact has been supported by various subsequent workers. It was also developed at this time that any hatch of young scale closely following the spray application was unable to find settlement in the oil coating and thus perished. This fact has been one of the most important considerations in red scale control by oil spraying.

The combination or double treatment of oil spray followed by fumigation quickly became the standard for red scale control on lemons, and remains today the most dependable treatment for this pest. The original interval of 2 days to two weeks between spray and fumigation has been little modified in commercial work. There has, however, been various changes in dosage and season of application. Although oil spray and fumigation are natural complements of each other for red scale, it is not possible to accomplish the best results if the dosage of either is lowered below that required for individual treatment.

During 1926 and 1927 a few growers spraying with oil in the summer

[2]California Citrograph, August, 1926.
[3]California Citrograph, March, 1926.

applied a fumigation the following winter. The results appeared comparable to the regular autumn combination.[4] The latter practice of summer spray and winter fumigation has increased in popularity until today it is the most common double treatment for red scale. Spray of the proper gravity oil appears to give fruit protection during the autumn better than fumigation and also controls the red spider, whereas winter fumigation is outstandingly the most effective against red scale on the wood. Since the lemon fruit crop is normally quite completely removed during the spring months before the red scale hatch gets well under way, the destruction of scale on the wood by winter fumigation should carry the tree into the active red scale breeding season in a highly satisfactory condition.

The application of white oil sprays to citrus in California has undergone a great change since the time of its introduction. The greatest influencing factor has been the deleterious effect of oil sprays to the citrus trees. The tolerance of citrus trees in different districts to the various viscosities of white oils has gradually become established. It has been found that lemons are more tolerant to high viscosity oils than oranges, and that even on oranges certain varieties, as tangerines or Mediterranean Sweets, are more susceptible to injury than are others; that lighter oils should be used in the hotter and drier interior valleys than in the cooler coastal areas. Oils are applied to lemons when they are most free of pickable fruit and the crop present is of a type least subject to drop; to oranges when the new crop has attained the size of a walnut and after the old crop has been removed. Winter work is particularly avoided because of possible adverse effects such as crop reduction and interference with coloration. In the case of lemons the tendency is toward Spring work to avoid hot weather influences on the crop. Such physiological factors influence the time of combination treatments for red scale more than the development of the insect.

Originally emulsions were used exclusively on citrus trees, later tank-mix was introduced and during the past season soluble oils have enjoyed a wide usage. Soluble oils promise ultimately to largely, if not completely, displace pasty emulsions and tank-mix in citrus spraying. Our observations of the past year indicate that soluble oil spreads somewhat better than emulsion and decidedly better than tank-mix; that there is less penetration of plant tissues with soluble oils than with pasty emulsions, even as pasty emulsions show less penetration and less build-up than tank-mix.

[4]Bulletin 4, California Fruit Growers Exchange, 1927.

THE INFLUENCE OF FORESTED AREAS ON PEA FIELD POPULATIONS OF *BRUCHUS PISORUM* L. (COLEOPTERA, BRUCHIDAE)[1]

By CLAUDE WAKELAND, *University of Idaho, Moscow, Idaho*

Data, intended to reveal whether the degree of infestation of pea fields by the pea weevil, *Bruchus pisorum* L., varied with the location of the fields in respect to timbered or mountainous areas, were accumulated during a three-year study in the Palouse Region of Northern Idaho and Eastern Washington (Fig. 108). The data were secured by making extensive field sweepings of growing pea vines, using a finely woven net of muslin mounted on a ten-inch frame. In the three-year study 10,292 weevils were captured in 113,850 strokes of the net. All of the field sweeping was done by only two individuals who endeavored to make the length of stroke, speed of movement, etc. as uniform as possible.

Variations in growth conditions, even in proximate fields, are so great that data secured in individual fields cannot be correlated accurately. Some of the factors affecting these variations are soil type, elevation, drainage, slope, exposure, previous farm practices, date, depth and rate of seeding, viability of seed, time of year, etc. A wide variation exists, also, in the numbers of weevils collected in successive group sweepings in the same field or in a small area of the field.

The degree of maturity of vines influences directly the number of weevils collected in different group sweepings in a single field. The rate of growth of the vines is so influenced by topography, soil type and moisture conditions that, within short distance range, areas which are in the early blossom stage or in the late pod stage or in various intermediate stages may be encountered. Adults are most numerous on plants that are in blossom, a fact that has often been reported also in literature, and when pods attain considerable size move to the vines of later maturity. Vines in low moist depressions frequently are succulent and supporting high populations of weevils when those in adjacent areas may be mature and nearly devoid of weevils. It appears that the only way broad general conclusions, indicating any significant trend in the degree of infestations of fields near to or remote from forested or mountainous areas, may be derived from the data of field sweepings is to treat the extensive mass of records as random observations. By grouping all observations within certain defined areas an attempt is made to show that there is a correla-

[1]Published with the approval of the Director as Research Paper No. 119 of the Idaho Agricultural Experiment Station.

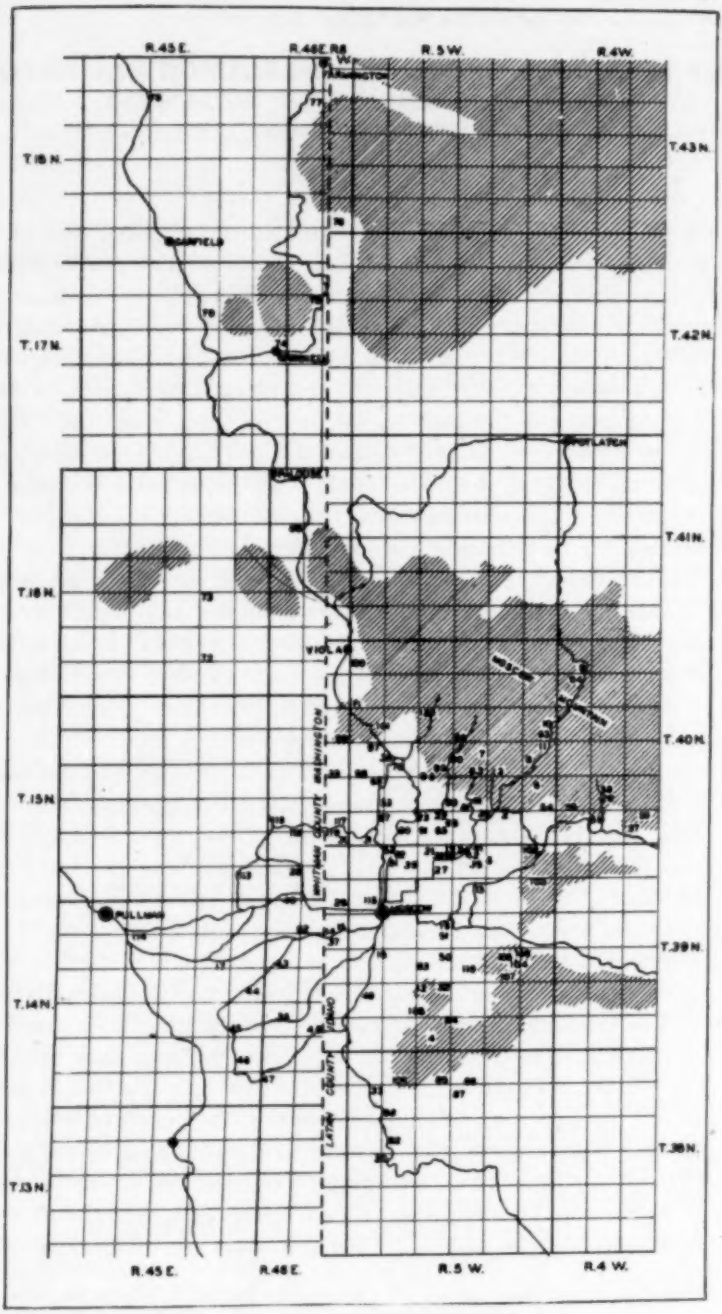

FIG. 108.—Diagram of the region in which studies were made. Forested areas on mountains or knolls are indicated by cross-hatching.

tion between the degree of infestation in a large, general area with respect to the influence of forested areas.

Fields in the same location for each of the three years' study were impossible to secure because of the rotation system of farming in the Palouse Region, where wheat fields are either summer fallowed or planted to peas each alternate year. For this reason, fields in which data were to be collected were selected at the beginning of each growing season. The earliest blossoming fields were chosen and sweepings were made in them at stated intervals throughout the remainder of the growing season.

All of the fields in which sweepings were made were numbered and their locations plotted on the map (Fig. 109) in order to group the data for analysis. Many observations have shown that one of the heaviest infested districts is that northeast of Moscow and near the base of Moscow Mountain. The pea-growing area accordingly was divided into a number of radial zones using location 2 in this area as the center and circumscribing successive circles one mile apart. All of the data for locations falling in each zone one mile in width were then assembled and averaged for the zone after having first been put on a uniform basis of the number of weevils collected in 100 strokes of the net. These groupings and averages are presented in Table 1.

TABLE 1. NUMBER OF WEEVILS COLLECTED IN 100 STROKES OF THE NET, THREE-YEAR AVERAGE

Radial zone No.	Number of weevils
1	17.02
2	15.92
3	1.90
4	10.38
5	3.17
6	7.17
7	4.29
8	1.55
9	1.45

Infestations are heavier nearer the base of Moscow Mountain as shown by even a casual observation of the data but it is apparent, also, that the decrease is not continuous as distance away from the mountain decreases. These facts are presented graphically in Fig. 110. The greater infestations in zones 4, 5, 6 and 7 than in zone 3 are explained by the fact that the ends of these zones come within the influence of the timbered areas on Thatuna Ridge and Paradise Ridge. These zones are affected in extent of population more by these ridges than by Moscow Mountain proper. Not until zones 7, 8 and 9 are reached do fields, in all excepting one direction, escape the influence of timber affording hibernation quarters for beetles.

Further information supporting the contention that populations of weevils in pea fields are affected by their distance from forested areas is

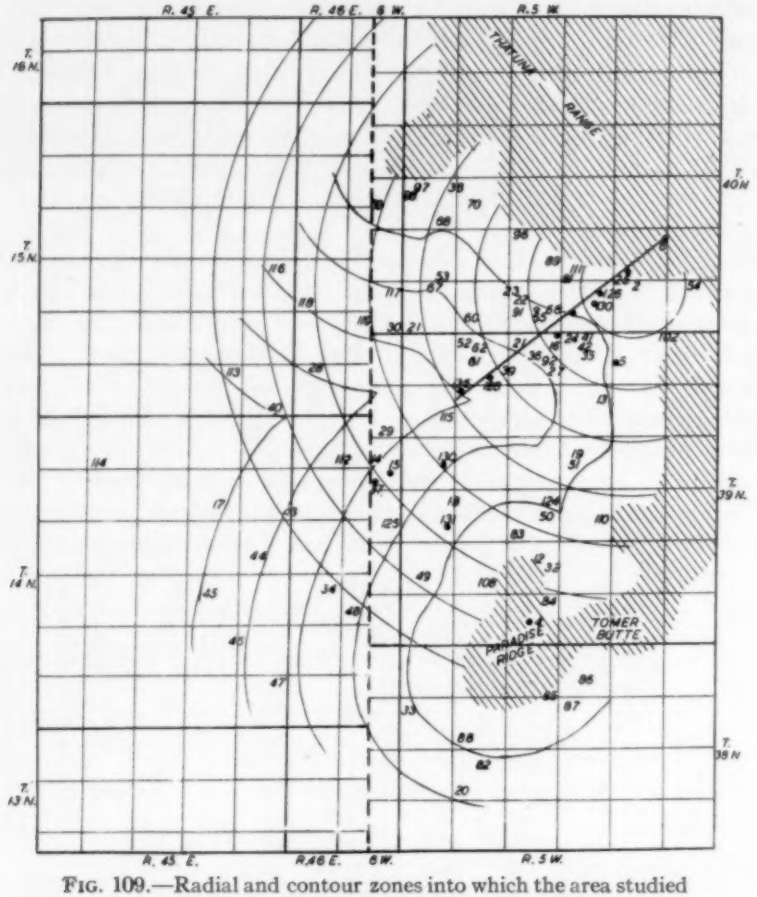

FIG. 109.—Radial and contour zones into which the area studied was divided for the purpose of classifying the field-sweeping data. Stations where field sweepings were made and where the bark of ponderosa pine was examined are numbered. The heavy diagonal line indicates the location of the base line discussed in the Journal of Economic Entomology 27:(2), p. 536, and the positions of flight traps are indicated by the black, solid circles.

found in Table 2 which records high populations of adults surviving beneath the bark of ponderosa pine along both of the above named ridges to their furthest extremities. Korab (1927) has reported *Bruchus pisorum* as flying two miles. Weevils are known to fly at least three

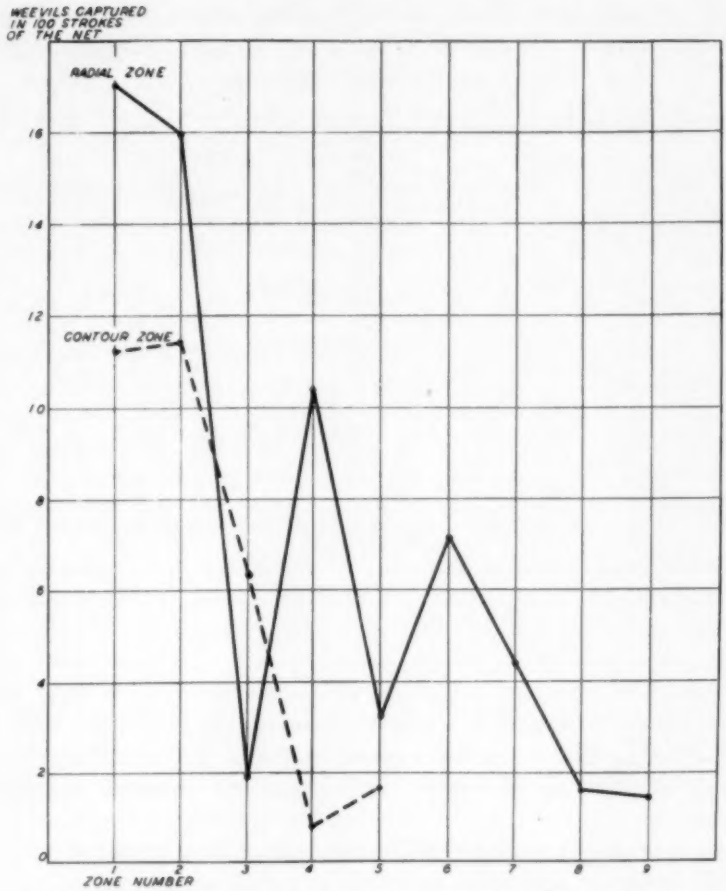

FIG 110.—Numbers of pea weevils captured in 100 strokes of the net in planted pea fields in radial and in contour zones. Three-year average, 1930–32 inc.

miles from pea fields to hibernate in forested areas as reported by Wakeland (1934).

Grouping the data into radial zones indicated that the degree of infestation of pea fields was not influenced by the distance the fields were from Moscow Mountain alone so the data were then re-arranged in zones one mile wide roughly paralleling the margins of the timbered area. When arranged in contour zones the summary of the populations in each zone is presented in Table 3.

TABLE 2. RECORD OF ADULTS HIBERNATING UNDER THE BARK OF PONDEROSA PINE, SPRING, 1932

Date	Location	Minutes of examination	Living weevils found
April 18	8	60	30
April 25	2	30	25
April 25	95	30	72
April 27	96	30	34
April 27	66	30	28
April 27	97	30	24
April 27	98	30	12
May 3	99	30	18
May 3	101	30	14
May 3	100	30	2
May 3	102	30	14
May 5	103	30	14
May 5	104	30	10
May 5	105	30	12
May 5	106	30	12
May 5	107	30	6
May 7	108	30	2
May 7	109	30	48
May 7	110	30	5

TABLE 3. NUMBER OF WEEVILS COLLECTED IN 100 STROKES OF THE NET, THREE-YEAR AVERAGE

Contour zone No.	Number of weevils
1	11.19
2	11.41
3	6.25
4	0.78
5	1.62

It is evident that there is a higher degree of correlation between the extent of field populations when considered from the standpoint of all the timbered area that affords hibernating quarters for weevils than from the standpoint of the forested area on Moscow Mountain alone. The conclusion is drawn that forested areas rather than higher elevations affect field populations of pea weevils, else populations would be greater adjacent to unforested high buttes, which was not found to be true.

The writer has no explanation to offer for the higher populations in the outermost contour zone. The populations in this zone, however, were so low as to be of no commercial importance in pea production.

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ATTEMPTS TO TRANSMIT EQUINE ENCEPHALOMYELITIS BY MEANS OF BLOOD SUCKING INSECTS, ESPECIALLY MOSQUITOES

By W. B. HERMS, C. M. WHEELER and H. P. HERMS, *University of California, Berkeley, Calif.*

The first discovery of primary importance in the field of arthropod-borne diseases was made in 1878 when Patrick Manson observed the development of a filarial worm in the body of a mosquito. With the work of Bancroft, Low and others he soon proved a mosquito to be the intermediary host and vector of *Filaria bancrofti*. It was, however, not until the epoch making work of Smith and Kilbourne in 1893 that the real foundation of Medical Entomology was laid. It will be remembered that it was Theobald Smith and F. L. Kilbourne who gave to the world the famous discovery that Texas Cattle Fever is transmitted by a certain species of cattle tick. It is a noteworthy fact that Bulletin No. 1 of the Bureau of Animal Industry of the United States Department of Agriculture is concerned with this discovery.

Within the short period of time between 1893 and 1910 (seventeen years) huge advances were made in the control of disease because of the discovery of the vector; we need only mention malaria, yellow fever, bubonic plague, typhus fever, African sleeping sickness, nagana, dengue fever, and Rocky Mountain Spotted fever, all diseases transmitted wholly or mainly by arthropods. Suspicion is frequently cast on insects as possible vectors of certain diseases whose mode of transmission still remains somewhat of a mystery. Such a disease is equine encephalomyelitis.

For several years past this possibility has been thought of and the theory found some support in the epidemiology of the disease, i.e., the explanation of the skip and jump occurrence of the disease seemed to call for a winged vector. However, it will be recalled by many present today that on September 26, 1912, an announcement was made by Rosenau at the Fifteenth International Congress on Hygiene and Demography that he had successfully transmitted poliomyelitis through the agency of the Stomoxys fly. This startling announcement filled the breasts of all who heard it with hope,—at last there seemed to be a basis for the control of this terrible malady. But a thorough test was necessary,—false security based on the control of the Stomxys fly was a terrible thing to contemplate. Dr. W. A. Sawyer and the senior author under the joint auspices of the California State Board of Health and the University of California were detailed to give the matter a severe test. This was

done, the work being started immediately and after nearly a year of the most painstaking and laborious effort it was announced[1] that we were unable to transmit poliomyelitis through the agency of the stable-fly (*Stomoxys calcitrans*).

In the light of certain similarities between poliomyelitis and encephalomyelitis you will appreciate the scepticism with which the senior author considered the possibility of insect transmission in spite of his own great desire to undertake an investigation of this important problem. It must not be forgotten that during 1930 one of every ten horses in the San Joaquin Valley showed symptoms of this disease and about 50 per cent of these died (Haring, Howarth and Meyer).[2] Also this information furnished us by Professor Knowlton from Utah is pertinent, "Equine encephalomyelitis made its first appearance in Utah in epidemic form during July, 1933. This outbreak can readily be divided into two distinct waves of infection: about July 1 a few cases of the disease occurred along the eastern shore of Great Salt Lake, near Ogden; by August 1 the disease had spread south and north along all the area easterly adjacent to the lake shore, and on northward into Idaho. The first wave reached its height about August 10; by September 1 most areas showed only a few scattered cases and the mortality rate had become much reduced. Approximately 500 horses succumbed in this first wave. Morbidity was estimated to be 27 per cent on infected ranches and 3.8 per cent in the counties in which the disease was prevalent. The mortality rate was estimated to be 43.9 per cent . . . . .

"The second wave began about September 18 at about the same point where the first wave began, and spread in the same directions, but had little tendency to spread to new uninvaded areas. Approximately 1500 horses succumbed in this second wave. The morbidity with relation to the total horse population in the counties affected was 6.9, with an average mortality of 53.2 per cent."

Professor Knowlton further states: "The economic importance may be briefly explained by what transpired during the past year in Utah. Approximately 2000 horses died from this disease, aggregating a total loss of from $200,000 to $300,000. In addition, approximately $12,000 was spent for serum as well as a lesser amount for other medicines . . . .

[1]Sawyer, W. A., and W. B. Herms. 1913. Attempts to transmit Poliomyelitis by means of the stable-fly (*Stomoxys calcitrans*). Jour. Amer. Med. Assn., Aug. 16, 1913, Vol. LXI, pp. 461–466.

[2]Haring, C. M., Howarth, J. A., and K. F. Meyer. 1931. An infectious brain disease of horses and mules (Encephalomyelitis). Univ. of California, Agric. Expt. Sta. Circ. 322, 14 pp.

Most of our trouble has occurred in the lower, marshy areas where mosquitoes, horse flies and other blood sucking forms are especially abundant."

Our first attempt to test the matter of insect transmission was made late in July, 1932.

EXPERIMENTS WITH HORN FLIES.—On July 28, 1932, a case of encephalomyelitis was reported from a ranch approximately one mile west of Orinda, California. The case was a Shetland pony (20 years old). In company with Dr. C. M. Haring of the Division of Veterinary Science, University of California, Berkeley, a trip was made to examine this case. Previously, Dr. Hogarty had found many small grey-white flies in the ears of this pony describing them as "louse-like" in movement. He captured one and broke the abdomen and found it to be filled with blood. Upon our arrival, approximately one hour later, no flies of this description were present. The ears were quite severely punctured supposedly by these flies. The ventral side of the horse showed a lesion apparently due to some mechanical cause on which numerous horn flies (*Lyperosia irritans* = *Haematobia serrata*) were feeding. A number of these flies were caught and brought into the Parasitological Laboratory of the Division of Entomology and Parasitology, at Berkeley, and liberated in a special cage. The pony was taken to the Veterinary Science Laboratory where it died that night.

The following afternoon, July 29, 1932, eleven of these flies were placed in each ear of a horse "B.O." furnished by the Veterinary Science Division. This was accomplished by means of muslin "ear-muffs" equipped with a cellophane window through which observations were made. The ear-muff was placed over the ear of the horse and fastened at the base by means of adhesive tape. The upper end was left open to receive the flies. The flies had been recovered from the rearing cage by means of shell vials—one fly to a vial, the vials being stoppered with cotton plugs. To introduce the flies into the "muffs" the senior author removed the cotton plug from the vial and retained the flies by closing the vial with his thumb. By placing the vial through the open end of the muff and removing the thumb, gathering the loose material around the vial, the captured fly escaped into the confines of the "muff". Twenty-two flies were introduced in this manner and the ends of the muffs tied with string. The flies immediately crawled down among the hairs in the ears and quickly began to suck blood. After a sufficient length of time had elapsed the flies were recovered by placing a piece of cheese cloth over each "ear muff" and by removing the muff from the ear the flies were thus captured. These were brought back to the laboratory and liberated in the

rearing cage. The entire operation covered a period of time from 3:30 P. M. to 5:00 P.M.

The same flies were captured the following day, one at a time in a small shell vial and the vials covered with bobbinette. By holding the covered end of the vial to the ear of a guinea pig the fly inside the vial was permitted to feed. Some began feeding at once and some required a considerable length of time.

July 30, 1932.

(Guinea pig No. 1). One horn fly allowed to feed on ear. Fly placed in vial with bobbinette over opening of vial. Two other flies of the same species fed on ear. Abdomens of each fly distended and red in appearance. No symptoms observed up to September 15, 1932.

July 30, 1932.

(Guinea pig No. 2). One horn fly allowed to feed on ear. Fly placed in vial with bobbinette over opening of vial. Puncture of ear by proboscis of fly evident from squeals and kicks. When proboscis was removed from ear a drop of bright red blood followed. No symptoms observed up to September 15, 1932.

During the latter part of the summer of 1932, we made a rapid survey of the San Joaquin Valley and the Owens River Valley into Nevada with Dr. K. F. Meyer and Dr. C. M. Haring, two of our best known authorities on this and other important diseases. During that time we saw many cases and took particular account of the possibility of insect transmission. As a result of these observations we undertook some experiments on our return to Berkeley with the black and white horse fly, *Tabanus punctifer*, which as well as the horn fly and the stable fly was present more consistently than perhaps any other species of blood sucking insect.

Experiments with Horse Flies.—On August 5, 1932, C.M.Wheeler left the party at Davis and was instructed to capture, alive, as many *Tabanus punctifer* as possible for immediate experimentation. Two specimens were captured that afternoon from a horse suffering from the disease. Saturday, August 6, 1932, a trip was made to Colusa, Calif. With the aid of Dr. J. A. Caldwell of that city, 7 specimens were captured some 4 miles north of the city from apparently healthy horses and with some local assistance 13 specimens were taken from a work horse in an orchard. On Sunday morning, August 7, another trip to Colusa was made and a large number of flies was caught by hand. Together with those taken at Sutter, Colusa and Davis, a total of 182 flies was captured. These were brought to Davis and placed in the cold room at 45° F. Monday, August 8, the cans with flies packed in ice were brought to Berkeley. Of the 182 flies only eleven were found dead. In order to make sure of a supply of

living flies, they were variously handled in the laboratory; placed in rearing cages, others in a frigidaire and still others in a large cheese cloth cage; also 36 were placed individually in shell vials covered with bobbinette and arranged in a tray with water-soaked strips of cotton pressed against the covered ends of the vials. A few of the flies were left in the original containers, i.e., wide-mouthed mason jars.

Moisture was furnished by placing pieces of water-soaked cotton inside the smaller cages and in the jars, the flies surviving very well. In the large cage a receptacle with water-soaked sand was placed. All but a few died in this cage. The cages were covered with a dark cloth to inhibit movement and to retain as much moisture as possible.

Beginning on August 9, 1932, a large number of the flies fed on a healthy horse at the Veterinary Division barn at Berkeley. Feeding was done by placing the flies in a wire screen cage open at one end, this being placed upon the back of the horse. The flies fed in the sun and seemed to be replete in from 10 to 15 minutes. In feeding, the flies were observed to use the forelegs as "feelers", much as a tick uses its forelegs, then by bringing the tarsi of the forelegs together separated the hairs of the horse and by pushing up with the hind legs the body was tilted at approximately a 30° angle as the mouthparts penetrated the skin with a bobbing movement of the head. The abdomen was in constant motion, much as a worker bee, during the process of feeding. Almost immediately or soon after feeding began, a droplet of "honey dew" like material was ejected from the anus of the fly. With the withdrawal of the mouthparts after feeding, a large drop of blood oozed from the wound. The flies remained quiet for a short time except for the "preening" movement of the forelegs and head, then they would crawl away and retire in the corners of the feeding cage where the sun could not strike them. Feeding appeared to be most active from 9:30 in the morning to about 4:00 P. M., or as long as the sun was fairly warm. In captivity the flies feed approximately once a week when engorgement is complete.

On Friday, August 12, two horses, B-68 and B-69 were inoculated intracerebrally with the virus of encephalomyelitis. Sunday afternoon, August 14, their temperature indicated the virus was taking effect and on Monday August 15, sixteen flies (*Tabanus punctifer*) were allowed to feed on B-68. They fed to repletion and were placed in the rearing cage. One was killed by being crushed, another died while four were given to Dr. K. F. Meyer for testing the presence of the virus. These flies had each fed approximately 10 minutes. At the same time horse No. 70 was inoculated subcutaneously with blood taken from B-68 and B-69, both inoculated horses. On Tuesday, August 16, an attempt was made to feed other flies

on B-69 (inoculated) but only a few days had elapsed since they had fed on a healthy horse and consequently would not feed. On August 17 flies which had bitten B-68 (inoculated) were placed on B-71, a normal horse, but would not feed. Trials were made on Friday, August 19, but with no success due to contrary actions of the horse as well as the flies. Horse B-68 (inoculated) was killed on August 16, and gave positive test for encephalomyelitis. Horse B-69 (inoculated) was killed August 17; also positive for encephalomyelitis. On August 19, a colt No. 74 was inoculated intracerebrally with the virus. In the ears of B-69 (inoculated) three ticks (*Otobius megnini*) were taken after the horse had been killed. Several saculated mites were also taken; these were apparently a stage in the development of *O. megnini*. The horse had been brought down from a canyon some 15-20 miles west of Davis, California.

Other methods of feeding the flies were tried. Fresh hamburger placed in the cages offered no attraction, neither did a live guinea pig also placed in a cage with several flies. Flies were observed to suck water from boards wet with water from saturated cotton—therefore blood from B-68 and B-69 (both inoculated horses) was placed on a soft board and allowed to soak in. The board was then placed in the cage, but the flies did not attempt to feed, and but one fly attempted to feed on filter paper soaked in blood.

A different type of feeding cage was then tried, consisting of a large kitchen sieve with handle and with a cotton stoppered hole 1″ in diameter cut in the top to permit introduction of the flies. The mouth of the sieve resting against the horse's body was reduced in diameter so as to afford a place for the flies to cling to during transfer and feeding manipulations. After the flies had fed they were placed in a small bobbinette carrying cage and returned to the laboratory where they were then placed in larger cages supplied with water soaked pieces of cotton.

August 23, 1932. Nine adult flies were allowed to feed for approximately 5 minutes on colt No. 74, inoculated August 19. The feeding of the flies was interrupted before complete engorgement. This colt (No. 74) died about 8 A.M. on August 24, with typical symptoms.

On August 27, seven flies which had previously (August 17) fed on horse No. B-68 (inoculated), fed readily on normal colt No. 71 after the colt had been thrown, stretched and hog-tied. On August 29, 1932 one fly fed on normal colt No. 73 after the latter had been treated in a similar manner.

On September 3, 1932 colt No. 71 was bled internally by Dr. Haring and the brain was sent to Dr. Meyer of the Hooper Foundation. No report was received. Colt No. 73 which had been subjected to supposedly

infected flies (fed on inoculated horse No. 68) was injected intracerebrally November 1, 1932, as a test for immunity. The horse died November 7 and Dr. Meyer reported that the brain contained plenty of virus, proving our experiment with the horse flies negative.

EXPERIMENTS WITH MOSQUITOES.—Observations made on the above mentioned survey in 1932 did not reveal a consistent distribution of any one species of mosquito nor even the consistent presence of mosquitoes. However, on the evening of May 3, 1933, at the New York Academy of Medicine, Major R. A. Kelser,[3] Veterinary Corps, United States Army, announced at a meeting of the Veterinary Medical Association of New York City that he had successfully transmitted the virus of equine encephalomyelitis from inoculated guinea pigs to a horse by means of the yellow fever mosquito, *Aedes aegypti*.

Following the discovery that he could transmit the disease to guinea pigs, Major Kelser permitted mosquitoes to feed on a horse and as a result, the horse contracted the disease and died within five days after the onset of symptoms. Blood drawn from the horse at the height of the fever and injected into a guinea pig produced the disease. Mosquitoes fed on the horse during the period of high temperature and subsequently fed on a normal animal likewise produced the disease. In Kelser's experiments, the larger percentage of deaths among the guinea pigs bitten by infected mosquitoes occurred on the sixth day following the mosquito bites. The mosquitoes were found capable of producing the disease as early as six days and remained infectious for at least thirty-six days. Kelser pointed out that it is possible that the mosquitoes when once infected, may remain infectious the rest of their lives as is the case in yellow fever and dengue. Thus the transmission of the virus of equine encephalomyelitis by mosquitoes is not merely mechanical but occurs, as Kelser observes, after the virus has undergone maturation, multiplication, or cyclical change within the body of the mosquito. Kelser also suggests that other species of *Aedes* mosquitoes may be vectors of the disease. The yellow fever mosquito does not occur in California as already stated but the disease has been widespread suggesting, in view of Kelser's work, the possibility of other mosquitoes acting as vectors. It is for this reason that the Division of Entomology and Parasitology undertook the work of testing the possibility of mosquito transmission of encephalomyelitis, in cooperation with the Hooper Foundation for Medical Research and the Division of Veterinary Science. This investigation was carried on continuously from the latter part of May, 1933 to

[3]Kelser, R. A. 1933. Mosquitoes as vectors of the virus of equine encephalomyelitis. Jour. Amer. Vet. Med. Assoc. Vol. 82, n. s. Vol. 35, No. 5, pp. 767–771.

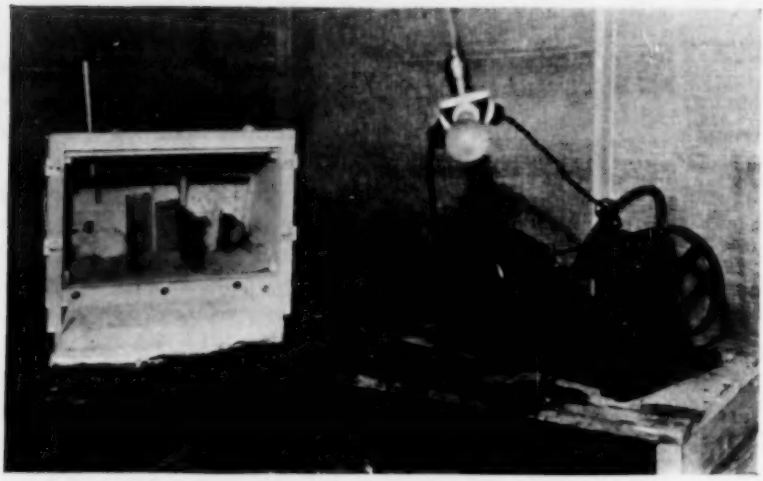

FIG. 111.—Showing method of mass feeding. Inoculated guinea pig separated from normal animal as shown in cage allowing mosquitoes to pass freely from one to the other. Suction apparatus with rubber tube was used to withdraw individual mosquitoes from the cage. Fan was used to prevent escape of mosquitoes in transter operations.

FIG. 112.—Shows method of feeding mosquitoes in lots of five on guinea pig.

about December 1, 1933. About two hundred guinea pigs were used in the tests. The following is a summary of these tests.

Major Kelser evidently used a mass feeding method but no information on the technique he employed was available. The yellow fever mosquito is well adapted for mass feeding experiments since it is a very voracious domestic mosquito. We used wild *Aedes dorsalis* (salt marsh species) also because it is a ready feeder. We also used *Anopheles maculipennis* because they fed readily and were easily available. We first devised a mass feeding procedure (Fig. 111) but because of serious difficulties were forced to abandon it for a more direct method. This direct method consisted of placing a lot of five mosquitoes into a small glass cylinder covered at both ends with bobbinette and putting the cylinder on the flank of a guinea pig (Fig. 112). The mosquitoes were kept in the cylinders between feedings. Keeping the mosquitoes alive from one feeding to the next was another difficulty with which we had to contend. We were fairly successful in keeping our mosquitoes alive by using strips of blotting paper as wicks, thus carrying moisture to the cylinders (Fig. 113).

Inoculated guinea pigs were secured from the Hooper Foundation where they were inoculated intracerebrally with .3 cc. of the virus. The animals used weighed about 250 grams. About ten hours after inocula-

FIG. 113.—Showing method of carrying moisture to mosquitoes by wicks of blotting paper.

tion, according to Miss Howitt, the virus makes its first appearance in the blood and the temperature begins to rise reaching its maximum, about 106° F. in approximately 48 hours after inoculation. At this time the virus is believed to be at its greatest abundance in the blood. Following the rapid drop in temperature, symptoms begin to appear such as paralysis of the hind quarters, salivation, grinding of the teeth, a general weakness, and finally death in about four days after inoculation. The symptoms in the guinea pig are very similar to those in the horse except on what might be called a miniature scale.

Because of the difficulties experienced in keeping the mosquitoes alive, actual experimental work was somewhat delayed, however, preliminary experiments were soon under way concentrating mosquitoes that had fed upon inoculated guinea pigs. These crude preliminary tests gave negative results. This presupposes, of course, that the next series of tests was made to ascertain if possible how long the virus remained in the body of the mosquito if at all. The procedure was as follows, mosquitoes were fed in lots of five on inoculated guinea pigs, e.g., taking a lot of five mosquitoes, these were fed on an inoculated animal ten hours after inoculation, then kept alive without food for six days which was the incubation period found by Kelser, when they were fed on one of the two normal animals used for this test. The next lot of five was similarly allowed to feed eleven hours after inoculation, this lot being used for a seven day incubation test. Thus the series of tests was extended to include a trial incubation period of 267 hours. The two animals used in these tests remained normal as did the animals tested for direct or mechanical transmission, i.e., absence of incubation period. *Aedes dorsalis* was the species of mosquito used.

Following this, we used one small animal, usually weighing less than 200 grams, for each lot of five mosquitoes; thus because of the small size of the animal increasing the chances of infection. Each lot of mosquitoes was fed upon the inoculated animal as nearly as possible to the time of maximum temperature and then kept for a definite incubation period. *Aedes dorsalis* and *Anopheles maculipennis* were the species used for this part of our experiment, and a very close check was kept on each animal subjected to the bites of the mosquitoes. Individual records were kept for each normal animal as well as for the inoculated animals used. Body temperatures of the normal animals were taken twice daily for a period of at least twenty-one days and following this the animal was kept under observation for several more weeks. Using *Aedes dorsalis*, the following possible assumed incubation periods (in days) were studied: 4, 6, 10, 11½, 12, 13, 14, 16 and 17, supplemented by the data in the preliminary

experiment already cited. Using *Anopheles maculipennis*, the following incubation periods in days were studied: 4, 5, 5½, 6, 8, 9, 10, 11, 14, and 16. The reason for the gaps in the incubation periods is due to the fact that the mosquitoes which were to be used for these particular periods died off before they could be used. Usually a number of trials was necessary before any lot of mosquitoes would live the required time and then at the end of that time feed upon the normal animal reserved for that particular incubation period. Three lots of mosquitoes, *Anopheles maculipennis*, were also fed upon an animal inoculated with a virus obtained from the East which is more virulent than the western strain. Incubation periods of 4, 5½, and 6 days were studied in this case. Our work with mosquitoes indicates a conclusion that the two species tested, *Aedes dorsalis* and *Anopheles maculipennis* are unable under the conditions of our tests to transmit equine encephalomyelitis from an inoculated guinea pig to a normal guinea pig.

In response to an inquiry relative to investigations by the U. S. Bureau of Entomology, the following information, under date of March 30, 1934, was received from Dr. Bishopp, Principal Entomologist in charge, Insects Affecting Man and Animals.

"Late last summer and during the fall, Mr. Carroll Smith of this division and I carried on some experimental work in cooperation with the Pathological Division of the Bureau of Animal Industry with reference to the transmission of encephalomyelitis by mosquitoes. We made an attempt first to find naturally infected mosquitoes. We went at this by collecting adult mosquitoes in and around stables in which encephalomyelitis was rampant. Seven collections were made over a period of 37 days during September and October, a total of 935 mosquitoes being tested by inoculation into guinea pigs. Of these 158 were *Culex salinarius* and *C. pipiens;* 548 were *Anopheles crucians* and 228 were *Aedes solicitans, A. taeniorhynchus*, and *A. vexans*. All of these tests were negative. Since we were not certain that these particular mosquitoes had fed upon infected horses and had no knowledge of how much time had elapsed after any possible feeding, of course this negative evidence is not very convincing. In connection with this work, some experiments have been carried on with *Aedes aegypti* and in a single instance this disease was transmitted successfully from guinea pig to guinea pig by this species of mosquito."

The work described in this paper concerned only four species of blood sucking insects, only two of which were fairly consistently present in localities where cases of equine encephalomyelitis had been or were seen by us on the survey noted above, namely the horn fly, *Haematobia*

serrata and the black and white horse fly, *Tabanus punctifer*. A third blood sucking fly, the stable fly, *Stomoxys calcitrans*, also consistently present, was given no test by us. *Aedes dorsalis* was used by us because it belongs to the same genus as does the mosquito found positive by Kelser, and commonly attacks horses, and *Anopheles maculipennis* is a common and widespread mosquito in the central valley of California. Both species were rather easily secured and fed well on our experimental animals.

There are many gaps in our work, but all of the tests made were well planned and painstakingly carried out. There are still other species of blood sucking arthropods that deserve testing, if insect transmission of equine encephalomyelitis under natural conditions is to be definitely ruled out or accepted.

LIZARDS AS A FACTOR IN THE CONTROL OF RANGE INSECTS[1]

GEORGE F. KNOWLTON[2]

The state of Utah has a total land area of 52,598,000 acres, of which less than 5 per cent is tillable. Approximately 5,000,000 acres consist of pure desert, inaccessible slopes, and bare rock. This leaves approximately 44,500,000 acres, or nearly 85 per cent of the entire land surface of the state, which is used for grazing. Thus, the livestock business is and in all probability will continue to be a major industry.

Livestock raising depends to a great extent upon the range; thus range land becomes one of the state's most valuable resources. Insects compete with the livestock for the grass, weeds, and browse plants of the range, each year robbing the stock of much food which otherwise would be available for the production of beef, mutton, horses, and the larger game animals. It is not uncommon for grasshoppers, caterpillars, or some other biting insects to cause conspicuous loss of forage in certain range districts almost every year. The total amount of inconspicuous damage, caused by aphids, leafhoppers, and large numbers of insects of many kinds, each causing a little injury, may even exceed that which is noted so strikingly when chewing insects strip the leaves from bushes, consume the grass, and leave small areas almost bare when severe outbreaks occur. Were it not for biological control factors, such as parasitic and predacious insects, insectivorous reptiles, and birds, much greater

[1]Contribution from the Department of Entomology, Utah Agricultural Experiment Station.

[2]Associate Entomologist. Publication authorized by Director, June 12, 1934.

injury would occur each year, with a consequent reduction in the carrying capacity of these range lands.

A study of the food habits of range lizards, carried on in Utah during the past four seasons, has clearly indicated that insectivorous lizards are a great asset to the livestock business. Lizards are abundant over much of Utah; most of the species are almost entirely insectivorous. Only one species, the chuck-walla, was found to be noticeably herbivorous. The feeding habits of the various insectivorous lizards vary somewhat, depending upon the size and habits of the species. In general, the larger forms had fed upon a greater proportion of large insects, while small species took a higher percentage of smaller insects.

Crotaphytus collaris baileyi (Stej.). The western collared lizard was taken in foothills of various parts of Utah, usually being collected upon rocks. An examination of 41 stomachs of this agile lizard yielded 37 adult and 89 nymphs of Orthoptera, practically all grasshoppers; 2 adult and 1 larval Chrysopidae; 3 Homoptera, including 2 cicadas and 1 leafhopper; 7 Hemiptera; 26 Coleoptera of which 2 were Silphidae, 2 Meloidae, 2 Cucujidae, and 2 Histeridae; 6 Diptera, of which 2 were robber flies; 4 adult and 9 larval Lepidoptera; 96 Hymenoptera, of which 24 were Andrenidae, 2 Sphecidae, and 1 Chrysididae; 3 spiders.

Crotaphytus wislizenii B. and G. The leopard lizard occurs on desert plains and lower foothills in various parts of Utah, sometimes in moderate abundance. Although this species eats smaller lizards of other kinds, it is otherwise beneficial. Stomachs of 90 specimens contained 137 adult and 52 nymphal Orthoptera, all but a few of which were grasshoppers, including 16 *Trimeritropus vinculata*, 17 *Melanoplus femur-rubrum*, 12 *M. mexicanus* and 9 *Hesperotettix viridis;* 3 Homoptera, *Okanagana bella;* 4 Hemiptera, all false chinch bugs; 7 Coleoptera; 13 Diptera, 9 of which were robber flies; 13 larval Lepidoptera; 27 Hymenoptera, 13 being ants; 10 lizards, 4 of which were *Sceloporus g. graciosus*, 5 *Uta s. stansburiana* and 1 *Cnemidophorus t. tessellatus;* 2 parasitic roundworms; 3 spiders.

Uta levis Stej. An examination of the stomachs of 45 Rocky Mountain tree *Utas* revealed a total food content of 1 Orthoptera, grasshopper nymph; 16 Homoptera including 2 beet leafhoppers, 2 other leafhoppers, 9 aphids and 1 fulgorid; 7 Hemiptera; 21 adult and 5 larval Coleoptera including 6 Coccinellidae, 2 Cantharidae, 2 Curculionidae, 2 Melydridae, and 1 Scarabaeidae; 31 Diptera including 14 Calliphoridae; 9 adult and 13 larval Lepidoptera; 55 Hymenoptera, 24 of which were ants; 2 spiders and 9 mites.

Uta stansburiana stansburiana (B. and G.). The northern brown-shouldered *Uta* is the most abundant, widespread, and probably the

most beneficial range lizard occurring in Utah. Besides being of special importance in reducing beet leafhopper populations (1, 2) in northern Utah desert breeding areas, it is of distinct value in reducing insect abundance in most range areas. This small lizard occasionally climbs up into low shrubs, but in practically all cases it was found upon the ground. Its food consisted almost entirely of insects obtainable on or near to the surface of the ground. Grasshoppers, moths, and other large, active insects are usually stalked, then secured through a quick spring. Such insects are grasped in the lizard's mouth and are beaten upon the ground with a vigorous "back and forth" motion before being swallowed. Table 1, based upon the examination of 3578 stomachs, shows that Homoptera, Hymenoptera, and Hemiptera were taken in greatest abundance. The large number of Homoptera are largely accounted for by 10,683 beet leafhoppers, *Eutettix tenellus* (Baker), as 2874 of the lizard specimens were taken around important host plants of the beet leafhopper, principally Russian thistle, blister cress (*Cheirinia repanda*) and *Atriplex rosea*. Other insects of this order included: 252 adults and 90 nymphs of other species of leafhoppers; 14 Fulgoridae; 3 Cercopidae; 11 Membracidae; 1320 Aphiidae; 6 Chermidae and 22 Coccidae. Hymenoptera included 2522 ants, and 61 Chalcididae, with small numbers of other families; of 3349 Hemiptera, 75 were Miridae, 2543 Lygaeidae, including 737 *Nysius ericae*, 1783 of the more or less beneficial predator *Geocoris decoratus*, and 72 Pentatomidae. The majority of the Orthoptera were grasshoppers, although 6 Mantidae and 5 Gryllidae were included. About twice as many caterpillars as adult moths and butterflies were taken. Spiders, mites and ticks were found in a large number of stomachs. Although a few ladybird beetles, parasitic Hymenoptera, Diptera, and other parasites and predators had been ingested, the majority of the insects found in the stomachs were injurious to plants.

Sceloporus graciosus graciosus (B. and G.). The sagebrush swift feeds upon insects and spiders which it captures upon the ground, as well as in shrubs and smaller trees. Specimens of this lizard have been collected repeatedly at a height of 2 to 4 feet from the ground, while a few specimens have been taken in junipers at elevations exceeding 7 feet. The lizards often descend from trees and bushes by jumping from branch to branch, then to the ground. Table 1 indicates that in the 1332 specimens examined, Hymenoptera were fed upon most abundantly, 2756 of the 3357 specimens found in stomachs were ants; Homoptera and Hemiptera were taken in almost equal numbers; Homoptera ingested included 601 aphids, 242 beet leafhoppers and 97 leafhoppers of other kinds; Hemiptera ingested included 257 adult and 382 nymphal *Nysius ericae*,

50 *Geocoris decoratus*, 68 Pentatomidae, and 44 tarnished plant bugs; Orthoptera consisted largely of grasshoppers, including 29 *Melanoplus femur-rubrum* and 21 *M. mexicanus*.

TABLE 1. TOTAL STOMACH CONTENTS OF ALL SPECIMENS OF *Uta stansburiana stansburiana* AND *Sceloporus graciosus graciosus*

	Uta stansburiana stansburiana (3578)				*Sceloporus graciosus graciosus* (1332)			
Hexapoda	Adult		Immature	Total	Adult		Immature	Total
Thysanura		1		1		0		0
Collembola		635		635		2		2
Orthoptera	344		749	1093	203		289	492
Isoptera	305		0	305	89		0	89
Neuroptera	27		60	87	17		11	28
Ephemerida	1		0	1	0		0	0
Odonata	23		0	23	1		0	1
Corrodentia	0		0	0	2		0	2
Thysanoptera	72		13	85	5		0	5
Hemiptera	2380		969	3349	642		809	1451
Homoptera	4539		8066	12605	672		809	1481
Coleoptera	863		99	962	540		79	619
Lepidoptera	343		699	1042	169		602	771
Diptera	968		464	1432	314		20	334
Hymenoptera	3822		12	3834	3357		0	3357
Insect eggs			0	0			9	9
Total Insects	13687	636	11131	25454	6011	2	2628	8641
Arachnida								
Spiders		802		802		139		139
Mites		172		172		56		56
Scorpions		5		5		1		1
Ticks		13		13		0		0
Crustacea								
Sowbug		1		1		0		0
Chilopoda								
Centipede		1		1		0		0
Nemathelminthes								
Roundworms		20		20		83		83
Lizards						1 *Sceloporus graciosus graciosus*		1
Other	Plant fragments, sand, pebbles, bird feather				Mollusc shell, sand, pebbles, plant fragments			

Sceloporus elongatus Stej. Stejneger's blue-bellied lizard was usually encountered around rocky roadsides or among trees; several specimens were collected at a height of 3 to 8 feet from the ground. An examination of 45 stomachs showed this lizard to be almost entirely insectivorous, the food consisting of 3 adult and 1 nymphal Orthoptera, grasshoppers; 2 larval Neuoptera; 1 Corrodentia, Psocidae; 6 adult and 1 nymphal Homoptera, including 2 beet leafhoppers, and 3 Fulgoridae; 21 Hemiptera; 80 Coleoptera, of which 25 were Chrysomelidae, 5 Coccinellidae, 4 Scarabaeidae, 1 Dermestidae, 2 Curculionidae, 1 Cerambycidae, 2 Carabidae, 1 Meloidae, and 1 Elateridae; 3 Diptera; 3 adult and 21 larval Lepidoptera; 121 Hymenoptera of which 103 were ants, 1 Apidae, 1 Sphecidae, 1 Mutili-

dae, and 1 Ichneumonidae; 4 spiders; and 1 centipede; 3 roundworm parasites were also recovered.

Sceloporus magister Hal. The desert scaly lizard consumes large numbers of ants, beetles, caterpillars, and in addition takes some plant materials, evidently for food in this case. The stomach contents of 24 specimens consisted of 1 Orthoptera, grasshopper nymph; 2 Neuroptera, one an ant lion; 13 Homoptera, 9 Fulgoridae; 14 Hemiptera; 63 Coleoptera, including 13 Chrysomelidae, 1 Buprestidae, 1 Coccinellidae, 1 Tenebrionidae; 1 Carabidae, 1 Dermestidae, and 6 Curculionidae; 1 Diptera; 4 adult and 31 larval Lepidoptera, including 29 *Plutella maculipennis;* 255 Hymenoptera, of which 229 were ants, 1 Andrenidae, 1 Apidae, 1 Mutilidae, 1 Vespidae and 1 Ichneumonidae; 1 spider; 1 young lizard, *Cnemidophorus t. tessellatus;* 13 berries; and 18 parasitic roundworms.

Sceloporus occidentalis biseriatus (Hal.). The western blue-bellied lizard appears to be largely insectivorous, the stomachs of 7 specimens yielding 3 adult and 4 nymphal Orthoptera, all being grasshoppers except one cricket; 3 adult and 6 nymphal Hemiptera, false chinch bugs; 4 Coleoptera; 4 lepidopterous caterpillars.

Phrynosoma douglassii ornatissimum (Gir.). Girard's short-horned horned toad feeds to a large extent upon ants. As ants keep large areas of the ground surrounding their mounds entirely bare of plant life, thus reducing the area of land available for the growth of forage plants, and as ant hills are abundant over much of Utah's range areas, lizards which consume large numbers of ants must be regarded as beneficial. Examination of 27 stomachs of this horned toad showed 520 Hymenoptera, of which 502 were ants; 5 adult and 1 nymphal Orthoptera, all grasshoppers; 2 Neuroptera; 2 Homoptera, including 1 beet leafhopper; 9 Hemiptera, 2 being predacious *Geocoris decoratus*, the rest plant feeders; 14 Coleoptera including 2 Elateridae, 2 Carabidae, 3 Curculionidae, 1 Coccinellidae, 1 Dermestidae and 1 Tenebrionidae; 2 Diptera; 1 adult and 5 larval Lepidoptera; 1 spider. The stomachs also held 117 parasitic roundworms.

Phrynosoma platyrhinos Gir. The desert horned toad fed to even a greater extent upon ants, 33 specimens having taken 1177 Hymenoptera, all but three of which were ants. Other food in the stomachs of the desert horned toad consisted of 1 adult and 7 nymphal Orthoptera, grasshoppers; 12 Homoptera, 3 of which were beet leafhoppers and 9 aphids; 18 adult and 2 nymphal Hemiptera, 13 of which were Pentatomidae, 8 being *Thyanta custator* and 3 *T. rugulosa;* 52 Coleoptera of which 14 were Carabidae, 6 Scarabaeidae, 5 Meloidae of which 4 were *Epicauta maculata*, 6 Elateridae, and one Coccinellidae; 1 Diptera; 9 larval Lepi-

doptera; and 1 spider. The stomachs also contained 136 roundworm parasites.

Cnemidophorus tessellatus tessellatus (Say). An examination of 219 stomachs of the desert whiptail lizard, collected from various parts of Utah, shows it to be a highly important factor in the control of range insects. Practically all of the insects ingested were injurious; beneficial species were rarely encountered among the stomach contents. These large lizards are active, ingest large quantities of insect material each warm day, and in the course of a year, each specimen is responsible for the elimination of several thousand caterpillars, grasshoppers, and other other injurious insects. The total stomach contents consisted of 47 adult and 124 nymphal Orthoptera, most of which were grasshoppers, but 5 camel crickets and 2 mantids were included;578 Isoptera; 1 adult and 33 larval Neuroptera; 59 Homoptera, of which 12 adults and 5 nymphs were beet leafhoppers; 32 Hemiptera, all of which were pests; 107 adult and 42 larval Coleoptera of which 29 were Carabidae, 5 adult and 3 larval Elateridae, 5 Cerambycidae, 3 Tenebrionidae, 3 Curculionidae, 21 Chrysomelidae and 15 Scarabaeidae; 20 adult, 31 larvae and 22 pupae of Diptera; 27 adult and 405 caterpillars of Lepidoptera; 40 adult and 2 larval Hymenoptera, none of which were parasites, 22 being ants. In addition were found 11 sowbugs; 8 insect eggs; 52 spiders; 12 scorpions; and one lizard.

Cnemidophorus gularis B. and G. Five specimens of the Sonoran whiptail lizard were collected in the Kanab and Orderville areas. The stomach contents consisted of 4 grasshopper nymphs; 1 aphid; 2 beetles; 9 lepidopterus caterpillars, and 4 spiders.

In addition to the insects listed, most stomachs contained large amounts of unidentified insect fragments. A number of stomachs contained sand, small pebbles, fragments of dry plant material, and occasionally other material, much of which may have been ingested by accident. Lizards at times deliberately lick up sand after feeding on insects. A comparatively few specimens of the insectivorous lizards contained succulent plant material which was thought to have been eaten intentionally.

These data, secured by microscopic examination of the stomach contents of 5446 range lizards, indicate that these lizards render a distinct service to the livestock industry in Rocky Mountain areas. Lizards are abundant in many parts of Utah. During the entire warm season they are active, ingest large amounts of food daily, and studies conducted with the brown-shouldered *Uta* (2) indicate that lizards digest their food rapidly; at least, this was the case with beet leafhoppers. Evidently

lizards should be rated along with parasitic and predacious insects and birds, as important biological control factors in range areas in which insectivorous lizards occur in abundance.

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THE SNAKE MITE (*OPHIONYSSUS SERPENTIUM* HIRST)

By C. R. SCHROEDER, *San Diego, Calif.*

Snakes as a whole are undisputably an economic asset in our agricultural world. They are the natural enemy of the small rodent and though no definite survey has been made of the rodent destruction that might have been, we classify our snakes as an efficient group of unsupervised rodent control workers. Secondly snakes make excellent attractive exhibits in the zoos of the world.

Any pest which may seriously threaten our snake population and which has world wide distribution should be investigated and a means of control established.

The snake mite, *Ophionyssus serpentium* Hirst, is not a newly discovered species nor has it only recently been considered a pest. It is variously known as the snake pest, snake scale mite and snake mite, by those who keep snakes in captivity. Specimens taken from a Pilot black snake, *Elaphe obsoleta obsoleta*, were identified by Dr. H. E. Ewing as the common snake pest of zoos, *Ophionyssus serpentium* Hirst.

A complete description of this gamasid mite was first given by Stanley Hirst in 1915,[1] who cites the earlier incomplete descriptions of Gervais in 1844 under the name *Dermanyssus natricis*, and also the more complete description of Megnin in 1884 who gave the generic name now used, *Ophionyssus*.[2] (Trachea opening through a pair of chitinous tubes or peritremes—suborder *Mesostigmata;* hypostome absent, sternal plate present—superfamily *Parasitoidea*. Modified chelicerae, fixed arm without seta, anal plate present and distinct from ventral plate in the female—family *Dermanyssidae;* minute dorsal posterior plate, genus *Ophionyssus*, Megnin, 1884. Syn.—(*Serpenticola* Ewing, 1923).)

The only practical consideration of this parasite was presented in a

[1]The proceedings of the Zoological Society of London in 1915. (Pp. 383–386).
[2]Manual of External Parasites, Ewing, pp. 14. Thomas 1929.

combined writing by Roger Conant of the Toledo Zoological Society and R. Marlin Perkins of the St. Louis Zoological Park, "This mite question" in the Bulletin of the Antivenin Institute of America, September '31.

The San Diego Zoological Society is fortunate in having Mr. L. M. Klauber, Crotalus authority, as Curator of Reptiles, assisted by Mr. C. B. Perkins, both of whom are keenly interested in the welfare of live specimens, and made our investigations possible. Our snake population is heavily infested with mites and the depression has assured their stay, since the present wood and stucco reptile house with tongue and groove flooring and wooden cages is ideally suited to their best development.

Zoological exhibits demonstrate the greatest number of mite infested snakes. The snake is unable to get away from the mites and remains as a constant source of choice food for an ever increasing mite population.

Klauber suggests the possibility of this species of mite being an importation, probably originally from Europe. He does not believe that it finds its way into Zoological collections from newly caught native species of snake, but finds its way into clean collections from snakes imported from infested groups. He states, "our native mite (in the southwest) is vermilion in color and is more common on lizards than on snakes, but is found on both. It never seems to be a serious pest in captive specimens, although it must often be brought in on native specimens and therefore we may presume that the local species have some native immunity which they lack for the snake mite *Ophionyssus serpentium*."[3]

The shedding snake leaves practically all the mites in the shed skin. In his native habitat he is able to emerge on clean soil. If conditions are favorable, a plentiful food supply, moisture and lack of temperature extremes his shedding which is a normal growth process, will be extremely rapid, a matter of minutes, and the process of shedding a frequent affair, at intervals of four to five weeks in the captive snake. However, the irritation resulting from excessive parasitism makes him a poor feeder, an infrequent shedder and when shedding does occur it is slow and incomplete resulting in an inevitable replanting of mites on his body. The snakes represented in the genera *Coluber*, *Thamnophis*, *Lampropeltis*, *Elaphe*, *Masticophis*, and *Pituophis* are most frequently parasitized, but we have just learned of a freshly caught *Crotalus adamanteus* at Miami, Florida, which was parasitized. We have infested *Crotalus ruber* in our own house, and were able to readily artificially plant mites on *C. ruber* and *C. confluentus oreganus*, resulting in their death, the first in sixteen

[3]A description of the mature mite and identification is being undertaken.

days, the latter in five. C. B. Perkins has never found mites on Boas or snakes of the genus *Natrix* (water snake).

Numerous authorities have assured us that mites are occasionally discovered on the freshly caught snake.

The following chart demonstrates that mites are capable in themselves of being primarily responsible for the death of the snake. Of ten snakes artificially parasitized, ten died in from three and one-half days to sixteen days without demonstrating other lesions than acariasis.

THE MITE.—The subject of this paper is anatomically described by Hirst,[1] *Body* long oval in shape. *Dorsal surface* furnished with numerous hairs, which are not very long and are distinctly curved.—There are two *dorsal shields*, the anterior one being comparatively large (length 0.3 mm., width 0.27 mm.), but the posterior one, which is situated far back near the hinder end of the dorsal surface, is very small and inconspicuous. Outline of *anterior shield* shaped almost like that of a lemon; twenty hairs are present on its surface.—The minute *posterior shield* is not provided with any hairs, but one or more pairs of minute punctuations, which may possibly represent the sockets of hairs, occur on it. On each side of the dorsal surface, a little behind the anterior shield, there are two distinct but very minute platelets, and they are followed posteriorly by about four very inconspicuous (obsolete) linear platelets, arranged in a longitudinal series. Numerous hairs are present on the posterior part of the ventral surface, but they are shorter than those on the dorsal surface. *Sternal plate* trapezoidal in shape, being much wider than long and furnished with only two pairs of hairs. *Genital aperture* normal in situation and appearance; it is protected by the usual thin membraneous operculum. *Genito-ventral plate* long and very narrow, the hinder end being sharply pointed. *Anal plate* pear-shaped, and it has the three usual hairs on its surface. *Peritreme* slender and rather short; it reaches a little further forward than the coxa

[1]The proceedings of the Zoological Society of London in 1915. (Pp. 383–386).

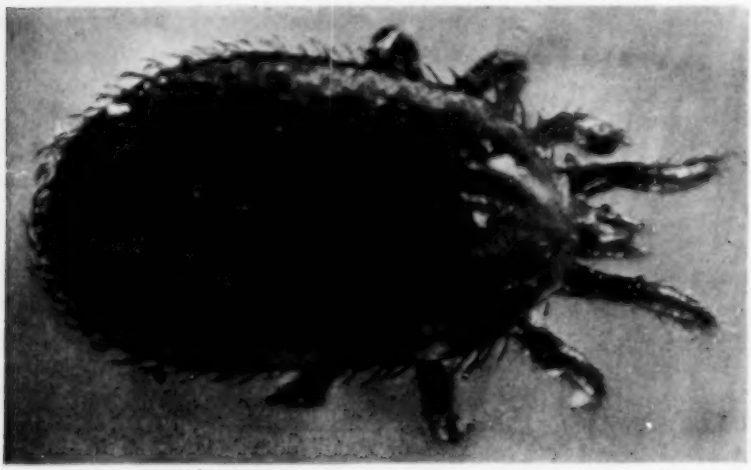

FIG. 114.—Adult female of snake mite 1.3 mm. long by 0.82 mm.

Host	Placed in parasite infested jar	Died	Lesions	Other pathology	Immature octopods	Adults	Hexapods
Cape San Lucas Racer, *Masticophis flagellum frenatus*	3/4	3/9	Acariasis	None	In excess Proportion 1:30–40	Few	None
Pacific Garter *Thamnophis sirtalis infernalis*	3/6	3/19	Acariasis	None	In excess Proportion 1:30–40	Few	None
Calif. Garter Snake, *Thamnophis ordinoides hammondii*	3/19	3/26	Acariasis	None	In excess Proportion 1:30–40	Few	None
Red Rattlesnake, *Crotalus ruber* Male, 76.3 gms. 120.6 gms.	3/31	4/16	Acariasis	None	In excess Proportion 1:30–40	Few	None
Pacific Garter, *Thamnophis sirtalis infernalis*	4/14	4/18	Acariasis	None	In excess Proportion 1:30–40	Few	None
S. D. Gopher Snake, *Pituophis catenifer annectens* 20.15 gms. 50 cms.	4/17	4/20	Acariasis	None	In excess Proportion 1:30–40	Few	None
S. D. Gopher Snake, *Pituophis catenifer annectens* Female, 250 gms. 106 cms.	4/21	5/8	Acariasis	Back injury Trauma	In excess Proportion 1:30–40	Few	None
Pacific Rattlesnake, *Crotalus confluentus oreganus* Male, 118.3 gms.	4/25	4/30	Acariasis	Loss of wt. in 2 days, 6%; wt. at death 111.6 gm.	In excess Proportion 1:30–40	Few	None
Pacific Garter, *Thamnophis sirtalis infernalis*	5/1	5/14	Acariasis	None	In excess Proportion 1:30–40	Few	None
Pacific Garter, *Thamnophis sirtalis infernalis*	5/2	5/10	Slight	None	In excess Proportion 1:30–40	Few	None

of the third leg. Fingers of *chelicera* short, and apparently without any trace of teeth. *Legs*. First leg the longest, and the fourth leg also long, the legs of the second and third pairs being shorter. Ventral surface of coxae without any strong spurs, only fine setae or hairs being present. There is, however, a very slight projecting spinule at the distal end of the inner surface of the coxa of the first leg.

Length 0.9 mm.

Colour (in spirit) reddish brown.

MATERIAL.—Five female examples found on a Couper's snake in the London Zoological Gardens (May 5th, 1909).

The above specimen is our common Indigo snake, *Drymarchon corais couperi*.

We find that the chelae are individually distendable and that they possess modified piercing structures.

Of twelve adult female specimens measured we found an average of 1.3 mm long x 0.8 mm wide; possibly the specimens Hirst studied were not fully developed.

We found the color to vary with the food intake. Recently engorged mites were more red than brown and the reptilian nucleated erythrocytes easily demonstrated in the content of the distended body. Those that were living free over an extended period were dark brown and their body content undetermined.

To insure a ready unstinted supply of specimens, for study, a glass jar one-half meter wide was used with a screened top to prevent the escape of the parasitized snake placed in it. Freshly autoclaved top soil, neither moist nor dehydrated, was used as the media for the free living of the mite. The upper edge of the jar was vaselined to prevent their escape. Two jars so furnished gave an ample supply of material with which to work. Frequent removal of soil to hunt for eggs and exoskeletons often destroyed great numbers of nymphs by crushing. In addition we constructed a flat window glass case in which the parasitized snake could be observed and the actual process of feeding by the mites studied. Rather than attempt to determine the number of eggs laid by the gravid female by a statistical study of proportion of nymphs to adults alone, we placed engorged females in sterile tubes containing autoclaved snake skin and muscle with a cork in the end pierced with a 22 gauge hypodermic needle for ventilation. The mites were unable to leave the tube and were readily watched and their movements recorded under a binocular dissecting scope.

Postmortems over a three year period showed evidence of mite infestation in better than three-fourths of all dead snakes. We had never felt that the acariasis had reached a stage sufficiently acute to be considered a primary cause of death until we demonstrated its possibility.

Soil removed from the floor of apparently mite free cages which had not recently housed snakes, yielded great numbers of eggs, young forms, exoskeletons, fecal masses and adults.

FIG. 115.—Mites, young octopods and one adult female removed from 252 cm. of snake skin surface.

The mite is capable of free living over an indefinite period, to again parasitize the snake when he is available. They will temporarily parasitize man and birds but the duration of their stay is limited.

The gravid female is responsible for the large fecal masses but she also deposits minute quantities. Size of fecal mass adhered to the snake is no indication of the size of the mite. A single adult may deposit five or six large fecal deposits in a day and numerous small ones. Number of deposits should not be an indication of extent of parasitism. It is uncommon to find exoskeletons on the snake.

The mating, egg laying, and molting are accomplished entirely free of

the snake. I do not believe it impossible to find eggs on snakes but it is apparent that the female has no method of planting and merely loses the egg as it reaches maturity. It is only slightly adhesive when first leaving the genital opening and will roll freely if once moved.

From our observation to date we conclude that the female is capable of laying one to three smooth, partially transparent, colorless, oval, thin-walled eggs daily. We have not actually determined the number of eggs that are laid during her life, but it is surmised from the proportion of immatures to adults that she must deposit in excess of thirty eggs during her life.

FIG. 116.—Hexapod resting after emerging from egg.

The egg apparently does not have a partially developed embryo at the time of delivery since it is quite transparent. The second day shows some density and during the latter part of the third day, varying with temperature, the body may be well defined, the legs pointing posteriorly, mouth parts down. When incubation is complete, approximately seventy-two hours, the egg fairly pops open zipper fashion and the hexapod emerges, temporarily exhausted by his effort. The hexapodal larva is active less than twenty-four hours at which time his movements become sluggish and a molt occurs. We have not observed a hexapod feeding on a snake host at any time. The newly emerged octopodal protonymph is extremely active and immediately seeks food. Before molting within a week's time his body loses its transparency. The second exoskeleton is short abdomened. The octopodal deutonymph is likewise active and grows posteriorly, so that the third and last exoskeleton has an extended abdomen.

SNAKE MITE (*Ophionyssus serpentium* Hirst)

	Color	Size average Length	Width	Fecal deposit	Duration
Egg.....	colorless opaque	0.325 mm x 0.211 mm			68+ hours incubation
Hexapod.....	colorless opaque	0.336 mm x 0.208 mm		? Not demonstrated	24–48 hrs. first molt
Protonymph	distinctly opaque	0.416 mm x 0.16 mm		? Not demonstrated	3–4 days+ second molt
Deutonymph	dark areas	0.600 mm x 0.272 mm		? Not observed	? third molt probably a week
Adult female	reddish brown to brown	1.307 mm x 0.816 mm		0.128 mm x 0.128 mm 0.272 base x 0.144 0.32 base x 0.288 0.304 base x 0.272 (Numerous smaller deposits, white to grey in color)	

Mites were not observed to fix themselves and feed as does the tick but rather they move rapidly from one location to another feeding under the scales and preferably where there is least movement or likelihood of being disturbed or crushed. They are most easily demonstrated under the chin shields. Gross external lesions are secondary to acariasis.

Snakes placed in the heavily infested observation jars gave immediate evidence of their discomfort and irritation induced by the mites. A red rattlesnake, *Crotalus ruber*, struck repeatedly at a metal weight suspended in the glass. Until exhausted the heavily infested hosts are continually in motion.

Water with or without an incorporated acaricide was never tolerated by the mite. If a section of soil was moistened that portion remained uninhabited by the mites if they were able to find a dry area.

The activity of the mites was directly proportional to the temperature.

SNAKE SCALE MITES

No.	Traveled per min.	Temperature
1	3.1 cm.	14° C
2	4.2 cm.	19° C
3	3.0 cm.	19° C
4	5.0 cm.	24.5° C
5	6.0 cm.	30° C
6	8.0 cm.	31° C
7	18.0 cm.	37° C

Overnight freezing 20° F, did not destroy all mites on a dead parasitized snake placed in the refrigerator. Like the common chicken mite, this parasite avoids light but he can readily be seen on the snake during the day.

Heat was always destructive, moist or dry. We feel that the mite problem can best be handled by the use of moist heat. Our observations lead us to believe that this mite is a facultative parasite, saprophytic when live snakes are not available.

To learn its extent of distribution, we sent an inquiry to the major zoos of the country. Apparently no large collection of reptiles is entirely free of mites. Means of eradication are many. All agree that strict quarantine of imported snakes is imperative if the infestation is to be controlled.

Acaricides of low toxicity in aqueous solution are best suited for demiting infested exhibits, such as an acetone extract of Derris root (rotenone) suspended in water. Such a dip does not interfere with the physiological function of shedding, is not toxic for the snake and yet we have found it entirely efficient in the destruction of mites.

At a temperature found in the average reptile house a mature mite is capable of traversing six inches (15 cm.) a minute. They are tireless travellers. We have observed them in motion without more than momentary hesitancy for half an hour which would be equivalent to traversing fifteen feet. Reptiles harbor many protozoan blood parasites and often develop bacterial septicemias following the acute stage of necrotic stomatitis, "mouth rot." This blood sucking mite is an excellent transmitter of organisms from cage to cage in his fecal deposits and during his life from snake to snake.

The mite has little or no resistance to the ordinary chemicals used as acaricides and any of them may be used with equal success off the snake to clean cages, soil and utensils, if they are used in solution. Their efficiency of course depends entirely on the thoroughness with which the cleaning is done.

Cleanliness is most important, but mite destruction can best be accomplished by removing all exhibits and cleaning the individual snake with aqueous solution of rotenone extract (in dilution recommended by manufacturer),[4] seal the house tightly and fumigate, or raise the temperature by the use of accessory heaters to 140° F. or higher for two hours or more.

Another efficient means for reptile house treatment is the use of a steam hose (where steam is available). Play the live steam on soil, walk, wire and into cracks and crevices. This moist heat has deep penetration and will definitely destroy egg and adult. Steam is not available in our reptile house and as a substitute we have used the common fire gun used

[4]List of Manufacturers may be obtained from the Bureau of Chemistry and Soils, Washington, D. C.

by poultrymen. The intense heat will destroy all life on the surface of enclosures but does not penetrate deeply in soil or in cracks between tongue and grooved flooring, and of course it will in time destroy the finish on painted cages. Miss Grace O. Wiley, Curator of reptiles at the new Chicago Zoological Park at Brookfield, Illinois, suggests besides thorough cleaning of the cage with soap and water, the placing of white outing flannel cloths in the cages over night which will attract hundreds of nymphs and adults. The infested cloths are scalded and again placed in the cages. Apparently these mites do not occur in the form of epidemics nor is there a seasonal variation, but they are seen in greatest abundance when conditions are ideal for their propagation, irrespective of location.

It is well known that mites which cause extensive damage to fruit have numerous predators. We are seeking an insect which might be carried into the reptile house in an effort to permanently control the mite infestation. The carnivorous species of the order *Coleoptera* might satisfactorily feed on snake mites. Where enclosure decorations—painted walls, trees and growing plants, must be considered before an extermination program, is begun, importations of carnivorous insects should be seriously considered.

Summary

1. The common snake mite pest (*Ophionyssus serpentium*, Hirst) is a facultative parasite.

2. Reproduction occurs off the snake in finely divided soil preferably rich in humus with normal moisture content.

3. The adult female lays single eggs, in excess of thirty.

4. The thin walled transparent eggs hatch within seventy-two hours.

5. Control measures must be directed toward the elimination of the mite from the snake's environment (cage and its accessories). It is impractical to spend time demiting snakes if they are to be returned to a mite infested cage.

6. Aqueous solution of Derris root (rotenone acetone extract) is entirely satisfactory as an acaricide for dipping snakes.

7. Heat, preferably moist, and physical cleanliness in combination with any acaricide should comprise the treatment for enclosures. (Avoid leaving surfaces moist with solutions that are harmful to the snake).

8. Quarantine and dip all incoming specimens in a rotenone extract aqueous solution. Prevent mite migration by using a water or oil barrier.

9. Autoclave or by some other method heat soil before placing it in the exhibit enclosure.

10. Where it is impossible to use hot water with cleansers, a fire gun or steam hose, the use of a predator might be resorted to. (A small species of carnivorous coleoptera).
(Entomologists in a local insectary are aiding us in the selection of such an insect.)

I desire to thank Mr. Earnest Sutton, Zoology student at San Diego State College for his assistance in the observation of mite activity in experimental containers; Mr. J. H. House of the Visual Education Center of the San Diego City Schools for assistance in the preparation of plates; Mr. C. B. Perkins and Mr. L. M. Klauber for specimens with which to work and assistance in the actual labor of the project.

MOSQUITO CONTROL IN CALIFORNIA UNDER THE CWA

By W. B. HERMS, *University of California, Berkeley, Calif.*

Bearing the date November 14, 1933, the following telegram, signed by F. C. Bishopp, was received from Washington, D. C. "Plans being made for extensive antimosquito work throughout country. Probably supervisors tools and supplies can be provided stop Laborers employed continuously prevailing wage scale. Wire estimate number laborers can use and number supervisors required in drainage operations. Funds available till February fifteenth only."

On the receipt of this telegram the writer called into consultation Mr. E. A. Reinke, Senior Sanitary Engineer, State of California, Department of Public Health and Mr. Harold F. Gray, Engineer and Executive Officer of the Alameda County (Calif.) Mosquito Abatement District. Both of these gentlemen had had wide personal experience and knowledge concerning the mosquito problem in this state. With the assistance of these experts an estimate was made of our mosquito control needs in relation to the above telegram and there was sent under date of November 15, i.e., same day request was received and over the signature of the writer, the following message to Dr. Bishopp. "Assuming your telegraphic inquiry concerns state as a whole can readily use one hundred and thirty thousand man days labor or twenty-two hundred men for three months period mosquito control in twenty-eight counties stop Average wage scale three dollars per day stop Need twenty-one supervisors to supplement supervision now available stop Competent unemployed men here for supervisor position stop Estimate materials tools rubber boots at fifteen thousand dollars stop Total estimated cost four hundred fifteen thousand dollars stop Please advise re administration of funds and general supervision of work".

The following letter dated November 15 was then received from Dr. F. C. Bishopp Principal Entomologist in Charge, Insects Affecting Man and Animals, "You will find enclosed confirmation of a telegram sent you yesterday with reference to anti-mosquito work which is being planned to be carried out under the Civil Works Administration.

"It is probable that the funds for this work will be turned over to the Bureau of Entomology, to be spent in cooperation with the various states concerned. It has occurred to me that you have quite a number of mosquito control projects in your state which might well be undertaken with these funds.

"While the laborers will be taken from the relief lists, they will not be treated as relief workers, but will be employed continuously at prevailing wage scales. No doubt some of the gang bosses and supervisors can also be chosen from the relief lists. However, it will be necessary, as you well know, to provide a considerable number of competent supervisors for the different projects. My idea is that these will be appointed as Agents of the Bureau of Entomology, and work under your direction as a Collaborator of the Bureau.

"It is our desire to get the work started as soon as possible so as to employ a large number of men during the winter. I shall appreciate having your plans as fully formulated as you can make them within a short time. It would also be well to indicate what tools will be required, and give us a list of men with their training and experience, for our use in selecting supervisors. We should of course like to have your opinion of the fitness of each of the men whose names you list."

In amplification of our telegram of November 15 and in reply to above requests, a communication and list of names of competent men was sent to Bishopp dated November 22, 1933. Apropos of this discussion the following is quoted from this letter, "All of the twenty already organized mosquito abatement districts in California amply deserve aid in effectively supplementing the work already done and in progress. Many of these districts are in agricultural areas with inadequate income even with the maximum tax permitted by law. With decreased income, I fear much of the benefit derived particularly in malarial districts, will be lost with a resultant increase in malaria incidence. In the estimate of cost my chief concern was for these districts. Also because of restricted area due to county lines and the like some of these districts have suffered because of mosquito breeding in adjacent areas not within the jurisdiction of the district. That situation could be most admirably handled in the manner proposed and is included in my estimate."

Next followed a letter under date of November 29, 1933, signed by Lee A. Strong, Chief of the Bureau of Entomology, United States Department of Agriculture. This letter stated in part. "The control of mosquitoes by such methods as drainage, filling and dyking is regarded as a valuable and reasonably permanent undertaking and the Civil Works Administration, in the desire to put a large number of men to work on useful projects as rapidly as possible, has seen fit to make this work a federal project.—You are designated as State Director, in your state, and you will be given an appointment as Collaborator if you are not already under appointment." Enclosed with this letter of appointment there was a letter dated November 28, 1933 signed by Harry L. Hopkins, Federal Administrator, and addressed to Mr. R. C. Branion, State Administrator, announcing the approval of the "Pest Mosquito Control Project", as a Federal Civil Works Project, Department of Agriculture, Bureau of Entomology supervising the same. This letter from Mr. Hopkins to Mr. Branion stated further specifically as follows: "You are hereby authorized and directed to furnish the designated representative of the above Bureau up to 1,684 persons at the following classes:

Supervisory 34—from $100 to $200 per month
Skilled —
Unskilled 1,650

"You are further authorized and directed to honor suitable vouchers for materials and other than labor expenses up to $15,000 drawn by the representative of this Bureau for this Federal Civil Works Project in accordance with the instructions which you will receive.

"The Federal Civil Works Administration will pay the cost of this Federal Project in full.

"This representative will communicate with you at once in regard to personnel. He will have complete charge of carrying out the project in your state and may alter the individual items of the personnel setup, both as to number and as to wage rates, provided that the maximum figure is not exceeded, and provided further, that the maximum compensations stated above are not exceeded."

Immediately on receipt of the above mentioned appointment I communicated with State Administrator Branion who stated that it would be necessary to take up the matter with Captain Edward Macauley, Engineer, who very promptly referred me to Captain Frank W. Hibbs, Assistant Engineer, who, in turn, requested that the whole matter be taken up with the Civil Works Administrator of Alameda County, Mr. S. H. Thompson. Mr. Thompson very graciously received me in his

office and at once assisted me in preparing Project No. SLF-25,—Administration of Pest Mosquito Control Project, which was approved by Captain Macauley December 13, 1933. This project authorized the appointment for a two months period of one Assistant Director at $200.00 per month, one Clerk at $125.00, one Stenographer at $100.00, one Clerk at $80.00, four Regional Supervisors at $175.00, four Regional Mappers and Surveyors at $150.00, and twenty-four County Supervisors at $150.00.

Under date of December 8, 1933 authorization was received from the Bureau of Entomology to perform travel in connection with supervisory and/or administrative duties on pest mosquito control,—subsistence per diem of $4.00 for Director and Assistant Director, and for assistants, per diem not to exceed $3.00. For personally owned automobiles an allowance of five cents per mile was authorized. An allotment of $7,000 was made by the Bureau of Entomology for travel and subsistance for the period ending February 15, 1934.

With these several authorizations, selection of personnel was undertaken, the first appointments being made December 15, 1933, of which the most important was the appointment of Mr. John A. Clark as Assistant Director. By reason of his training (graduate in civil engineering, Stanford University, 1930) and experience, he having been Division Foreman and Inspector for the Alameda County Mosquito Abatement District during a period of three years, Mr. Clark was particularly well qualified to undertake this position. With the exception of the Assistant Director, all persons appointed were theretofore unemployed and registered at a C.W.A. employment office. A convenient and adequate room in Agriculture Hall on the Berkeley campus was set aside for headquarters through Dean C. B. Hutchison of the College of Agriculture of the University of California.

Fortunately the widely advertised annual meeting of the California Mosquito Abatement officials took place on the date last mentioned, (December 15) which enabled us to canvass the needs of the various districts already organized, and by reason of the fact that there were also present representatives from many other parts of the state interested in mosquito control, a rather comprehensive knowledge was gained as to the state-wide needs, carefully checked by Messrs. Reinke, Gray and the Director, all well acquainted with the state-wide mosquito problem. To this meeting there had been invited applicants for supervisory positions, and with the regular program of papers, and intensive training during the following two or three days there was constituted a training school of considerable value.

In accordance with our original plans the state was divided into four regions with a regional supervisor in charge of each region, together with a regional surveyor and mapper. Region I, Coastal Counties, with Mr. Herbert Foster, Jr., and later, Mr. Dov Ber Krimgold as Regional Supervisor, consisted of the following counties: Alameda, Contra Costa, Marin, Monterey, Napa, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma. Region II, Sacramento Valley, with Mr. Thomas Rush as Regional Supervisor, consisted of the following counties: Butte, Colusa, Glenn, Placer, Sacramento, Shasta, Sutter, Tehama, Yolo and Yuba. Region III, San Joaquin Valley, with Mr. J. S. Yuill as Regional Supervisor, consisted of Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus, and Tulare counties. Region IV, southern California, with Mr. John Spencer, and later, Mr. W. T. Ingram, as Regional Supervisor, consisted of Los Angeles, Orange, Riverside, San Diego, San Luis Obispo, Santa Barbara and Ventura counties.

Since there were not enough supervisors for each county in which work was contemplated, frequently two counties were combined under one supervisor. Of the total number (29) of supervisors (Assistant Director, Headquarters, Regional, Surveying, and County) employed on this project, including replacements, twelve were graduates in engineering, University of California (6), Stanford University (3), Lehigh University (1), Iowa State (1), Massachusetts Institute of Technology (1), twelve were graduates in entomology, and five were not technically trained men, but were experienced in mosquito control or drainage operations.

Besides the Director, who carried this task in addition to his regular University duties, and without salary, the headquarters staff consisted of the Assistant Director, Mr. John A. Clark; Headquarters Engineer, Mr. Clyde F. Smith; Equipment and Inventory Engineer, Mr. Lawrence Warner; Culicidologist, Mr. Herbert Herms, and three clerks. Unless one has had experience with CWA operations, little conception can be had of the enormous amount of work devolving upon a headquarters organization. I wish particularly to express my profound gratitude for the loyal and self-sacrificing support which was given me through the period of our CWA operations by the headquarters group and, for that matter, by all personnel in supervisory capacities,

As soon as instructions were given the several supervisors were dispatched to the parts of the state where their field operations were to be. Each man was instructed to first contact the County CWA Directors. With few exceptions, our men were cordially received and most valuable cooperation was given us. Our supervisors selected the local mosquito control projects, which were then inspected by the Regional Supervisor

and properly surveyed and mapped. Each project was then submitted to headquarters for the attention of our headquarters engineer after which each project was submitted to the Director for approval. Next, each project was submitted to the office of the State CWA in San Francisco for approval. Frequently much time was lost in this process. In spite of the fact that the Federal Civil Works Administrator had stated in his letter to Mr. Branion, State Administrator,—"You are further authorized and directed to honor suitable vouchers for materials and other than labor expenses up to $15,000.00 drawn by the representative of this Bureau for this Federal Civil Works Project, in accordance with the instructions which you will receive", the chief cause of serious delay in getting our work started was the fact that we could find no way satisfactory to the State CWA for the purchase of tools and equipment. Finally this matter was adjusted, but, had it not been for the fact that in the meantime some county cooperation was afforded us, it is doubtful whether we could have operated at all during the first four or five weeks.

The first working project, with borrowed tools, was actually begun December 29, 1933 in Alameda County. Work on our projects had hardly begun when, on January 18, orders were received from Federal Civil Works Administration to curtail the work generally, and allowing no new men. As a consequence, when the Federal Pest Mosquito Control Project terminated on February 15, 1934, the number of men we had at work was 710 as against the original allotment of 1650. There were at that time 30 working projects. We had used 37.5 per cent of the 187,338 man-hours alloted for the period, December 15, 1933 to February 15, 1934.

The California Civil Works Administration was agreeable to extending the project beyond February 15 provided proper sponsorship was secured. The State Department of Public Health, which had sponsored mosquito control operations in the state during previous years, accepted this sponsorship through its President, Dr. Howard Morrow. The supervisory personnel remained intact. A new administrative project 600–03X with travel allowance was approved, but with the termination of the Federal Project our special allotment of laborers was lost, and it was necessary to secure labor from the county CWA quotas, which were being reduced weekly. In spite of these handicaps, we were able to secure men, though in every case the number of men was far below the number approved for the several projects. Under this new arrangement additional projects were approved, making a total of 55 working projects. However, work was performed on but 46. Mosquito control under

the C.W.A. terminated March 29, 1934, though the administrative project continued with progressive reduction in personnel until April 26, 1934.

Mosquito Studies.—The study and collecting of mosquitoes was mainly confined to the vicinity of the various CWA mosquito control projects, larvae or pupae being the main objective in order to locate breeding places. Mosquito material was either received or collected from 22 counties in which work was being carried on and then classified and card catalogued as to locality, date, species, place collected, etc. A concentrated inspection trip was undertaken in Marin and Sonoma counties to locate in that area every possible breeding place of the salt marsh forms *Aedes dorsalis* and *A. squamiger*.

A very interesting difference was noted in *Aedes dorsalis* between the salt marsh form and the inland form which have hitherto been regarded as varieties. There are very definite specific differences in both the larvae and the adult male terminalia, and it is concluded that *A. dorsalis* really presents two species namely *dorsalis*, the inland species, and probably *caspius*, the salt marsh species. A manuscript dealing with this matter has been prepared for publication by Dr. S. B. Freeborn and Mr. Herbert Herms.

Culex federalis was for the first time taken in an aquatic stage, in this case a pupa, which was found in a heavily tule shaded pool at the Ceres sewer farm. The collection of mosquitoes in this project differed from previous collecting in that this work was done during the winter and early spring and the material consisted mainly of larvae and pupae and, of course, overwintering mosquitoes. Previous collections were made during the summer and consisted almost wholly of adult mosquitoes. Over one hundred and fifty collections were made consisting often of very many larvae which were reared in the laboratory, entailing much careful manipulation.

Fifteen species of mosquitoes in various stages of development were brought to headquarters and classified as follows: *Anopheles punctipennis*, *A. pseudopunctipennis*, *A. maculipennis*, *Theobaldia inornata*, *T. incidens*, *Aedes varipalpus*, *A. squamiger*, *A. dorsalis* (salt marsh and inland forms), *Aedes vexans*, *Culex tarsalis*, *C. pipiens*, *C. erythrothorax*, *C. stigmatosoma*, *C. federalis*, and *C. apicalis*. In this as well as other phases of our work we were ably assisted by Dr. S. B. Freeborn.

Control Operations.—The following extracts taken from the general reports of the regional supervisors illustrate the types of control operations undertaken under the CWA in California.

REGION I—COASTAL COUNTIES.—The ten counties included in this region border on the San Francisco Bay and other salt water bodies. With few exceptions the breeding areas are of the salt marsh type. The dominant species of mosquitoes are *Aedes squamiger* and *Aedes dorsalis*. The females of both species are capable of travelling long distances from their breeding places and with favorable atmospheric conditions and a fairly good prevailing wind will travel as far as forty miles.

In most cases the work consisted of digging open drains to permit free ebb and flow to all parts of a marsh. Due to the fact that in recent years considerable areas of reclaimed land remained uncultivated and unattended it was necessary in some instances to repair levees and fill in cracks in order to eliminate existing and potential breeding areas.

Project SLF-1017X (99) Warm Springs (M. A. D.)*—Alameda County.—The project is located in the vicinity of Warm Springs along the eastern shore of San Francisco Bay. The work consists of digging open drains to permit free ebb and flow to all parts of the marsh. Sixty per cent completed.

Project SLF-102 Three Cities (M. A. D.)—San Mateo County.—This project was chosen to forestall the creation of a bad breeding area affecting several communities in San Mateo County. The work consisted of building a redwood bulkhead to prevent destruction of the levee. One hundred per cent completed.

Project SLF-1022X (132) San Rafael (Marin Co. M. A. D.)—Marin County.—This project will eliminate a large, potential breeding area three miles south of San Rafael and close to other communities in Marin County. The work consists of building a redwood bulkhead and reinforcing levee to prevent destruction of levee by tidal wash. Lumber contribution of M. A. D. Seventy-five per cent completed.

Project SLF-1037X (164) Sonoma (M. A. D.)—Sonoma County.—This project will rid the cities of Sonoma and Napa counties of one of the closest breeders of salt marsh mosquitoes. The work consists of digging open drains to connect breeding pools and direct water to existing tide gates, the placing of new tide gate; all in the vicinity of Sonoma (city). Ninety-five per cent completed.

Project SLF-1016X (98) Solano County (M. A. D.).—The work consists of digging open drains to conduct water from low spots on marsh land to tide gates. The tide gates supplied by Solano County Mosquito Abatement District. Sixty per cent completed.

Project SLF-1062X Richmond—Contra Costa County.—The work consisted of digging open drains to permit free ebb and flow to all parts of marsh. This project was a completion of work started by the Contra Costa County Civil Works Administration. One hundred per cent completed.

Project SLF-1033X (158) Alviso—Santa Clara County.—The project is located five miles from San Jose and about three miles from Sunnyvale. This area breeds *Aedes squamiger* and *A. dorsalis* which disperse to many communities along the Bayshore Highway. The work consists of digging open drains to conduct water to existing tide gates; repairing levee; and constructing a short section of bulkhead. A small tide gate was installed. Ninety per cent completed.

*M. A. D. = Mosquito Abatement District.

REGION II—SACRAMENTO VALLEY.—Both Culicine and Anopheline larvae were quite plentiful until the heavy storm on December 27th. Thereafter no Anopheline larvae were found until late in March. Culicine larvae were quite plentiful through the winter. A large flight of hibernating *Anopheles maculipennis* infested the whole lower valley from the third week in January until about the middle of April.

On February 8th quite a number of larvae were taken in the Feather River bottoms. These proved to be the first *Aedes* larvae taken this season in the Sacramento Valley region and were identified by Dr. S. B. Freeborn as inland, fresh water *Aedes dorsalis*. From a collection of adult mosquitoes taken mainly by Mr. Herbert Herms during January, February and the first week in March, it was ascertained that *Anopheles maculipennis* constitute about 99 per cent of the early spring mosquitoes in the valley. In addition the following species were taken, *Anopheles punctipennis*, *Theobaldia incidens*, *Culex tarsalis*, and *Culex pipiens*. These as well as *Anopheles maculipennis* were all females and believed to be hibernating through the winter, which was very mild. During April Anopheline larvae were widespread and plentiful.

Project SLF-134 (SLF-1024-X) Yuba and Sutter counties.—In the City limits of Marysville a clearing and ditching project (SLF-134) from the Simmerley Slough S. P. Bridge to the Feather River concentrated and drained flood pools along the outlet of Ellis Lake and the lower end of Nigger Jack Slough. A main drain one-fourth mile long and averaging 4′ x 3′ was constructed to grade through the low area of this jungle breeding area which will be fairly permanent for drainage purposes.

Project SLF-154 (SLF-1031X) Yuba and Sutter counties.—North of Marysville Airport a ditch averaging 2′ x 3′ with a maximum cut of 4½′ in places and 8000 feet long was constructed to drain about 2½ miles of shallow borrow pits along the Brown's Valley Grade south and west into Nigger Jack Slough. This job is of major importance as it drains some 80 acres of Anopheline breeding area all of which is within flight range of Marysville and Hallwood. This job was left about one-third done.

Project SLF-131 (SLF-1021X) Butte County.—Project SLF-131 was a slough cleaning project about 3½ miles below Durham. This slough is one of the major drains of the Durham vicinity and by clearing out the obstructions from the lower end on up the slough, the water level has been lowered two or three feet. The slough was cleared for a distance of between 3 and 4 miles to a point south of the Nelson-Butte City Road. The work consisted of removing logs, trees, willows, tules and brush from a strip 60 to 95 feet wide. In some places the water was over the men's heads. This slough had never been cleaned before and was in a bad condition for a channel that is used for drainage purposes. The entire length extends through a rice area of 2500 acres, which is populated in the immediate vicinity by about 500 people. This project was supervised by Mr. F. M. Butler, and the tools were furnished by the Durham Mosquito Abatement District.

Project SLF-156 (SLF-1032X) Butte County.—In the vicinity of Gridley and Biggs Project SLF-156 consisted of mucking the tules and willows out by the roots in the drains of Reclamation District 833. These drains take care of all the area in and

around the two towns, which have a combined population of over 2500 people. About nine miles of drains were thoroughly cleaned.

Project SLF-1054X Tehama County.—North of Vina cleaning and straightening of Vina slough dried up a large marshy area on the Hanna Ranch. This spot covered many acres which were bad anopheline breeders. A straight cut about 2′ x 10′ was constructed through the middle of this area about ½ mile long.

Project SLF-1075X Shasta County.—In Shasta County work was outlined along the Sacramento River area between Redding and Cottonwood, at Millville and in the Fall River Valley in the northeast tip of Shasta County near McArthur, Glenburn, and Fall River Mills. Projects Nos. SLF-193 and SLF-152, later supplemented by Project No. SLF-1075-X covered all this work.

In every instance, due to the huge amount of work required, the heavy type of the work and the splendid interest and cooperation shown by the local people, several tractors, teams, pilepullers, ditchers, etc., were used to very good advantage. When the project was first started laborers numbering as high as 75 men were worked, but these crews were rapidly reduced, until after February 15th only five men were left. These men were used as foremen of State camp crews. At Clear Creek fifteen miles of old drains were cleaned and about three miles of new drains constructed. At Redding sixteen miles of land were cleaned and drained. The major part of the new drains are in the Cottonwood District. Here a tract two miles in length was cleaned and drained within the town and five miles adjacent to the town were likewise cleaned and drained.

The major portion of heavy equipment was used to brush and bring to grade Anderson Creek from the county bridge up creek, through the properties of the California Lands Inc. This is a distance of nearly two miles. Outside the town a stretch of ten miles was drained. All cuts made were ten feet wide and had a maximum depth of three feet in places. Most of the distance was through very heavy brush which necessitated the pulling out by the roots of willow trees from 8″ to 12″ in diameter.

Fish Planting.—All drains around the Shasta County Hospital, Anderson Fair Grounds and all the country schools in the Anderson-Cottonwood Irrigation District were cleaned. The fish breeding pond, which is a large clay pit at the abandoned brick works north of Anderson, was cleaned and put in first-class shape. Sixteen cans of fish averaging approximately 1,000 fish per can, were transplanted from this hatchery to Fall River Valley, a distance of 90 miles. The fish planting equipped truck was used for this work.

Work done on Project SLF-200 (SLF 1040X) at North Sacramento consisted of digging a trapezoidal ditch 5′ wide at the bottom and 13′ wide at the top averaging from 2′ to 10′ deep. This large drain is 800′ long and is divided in the center by a railroad embankment through

which a 60′ culvert was tunneled and jack-driven by hand in hardpan with the use of powder. This was quite a ticklish job as dynamiting in a tunnel 36″ in diameter below a high railroad fill must be done very carefully. The above work was done on the west side of North Sacramento near the American River Flood Control levee.

Region III. San Joaquin Valley

Project SLF-130 (1020X) Visalia—Tulare County.—Clearing and a small amount of filling along St. Johns River. This work has made it possible for the local abatement district to oil and plant fish in seepage holes which were heretofore inaccessible because of dense river bottom growth. Wherever possible, holes were filled.

Project SLF-1064X Porterville.—Filling outflow ditch from old mill in city park. A small but bad breeding area was permanently eliminated.

Project SLF-149 (1027X) Madera—Madera County.—Cleaning and grading of irrigation ditches will greatly expedite the mosquito control carried on by the county health officer.

Project SLF-100 (1018X) Lodi.—Clearing along the Mokelumne River about 50 per cent completed. Since February 15 labor for this project has been used on a local allotment project near Woodbridge. This work can be extended for some time.

Project SLF-136 (1026X) Stockton—San Joaquin County.—Draining of Homestead slough to carry off water from natural gas wells. This job will be completed this week if pipe is obtained in time.

Project SLF-1094X—Modesto. Stanislaus County.—Clearing and draining a high-water channel on Beard Brook. Refusal of one property owner to sign releases has made it impossible to complete all the work. The worst part of this channel has been cleared and about 70 per cent of the drainage in this portion will be completed this week. Herbert Herms collected Anopheles sp. here.

Region IV.—Southern Counties.—The fact that southern California is subject to torrential rains is of great importance in mosquito control. Drainage ditches adequate to carry off storm waters are of such proportions that small flows become stagnant. Large basins of water collect and drain away slowly as the ground permits.

The southern California coast is a series of heads and low valleys. Nearly all of the larger streams that enter the ocean do so by means of a wide flat tide marsh. *Aedes taeniorhynchus* is the dominant salt marsh species here.

Saticoy Project SLF-160 or 1092X—Ventura County.—Work of channeling two drainage ditches through the town of Saticoy has been started and is at this time about 70 per cent complete. Additional work should be done on the main drainage ditch. Anopheline mosquitoes were found here.

Terminal Island Project SLF-224 or 1045X—Los Angeles County.—This area is a low salt marsh that has been very difficult to work. Although lower tides cover the area, the grasses are so thick that the water does not wash. Large broods of mosquitoes have been traced to this area in previous years. Trenching the marsh to provide wash is approximately 50 per cent complete.

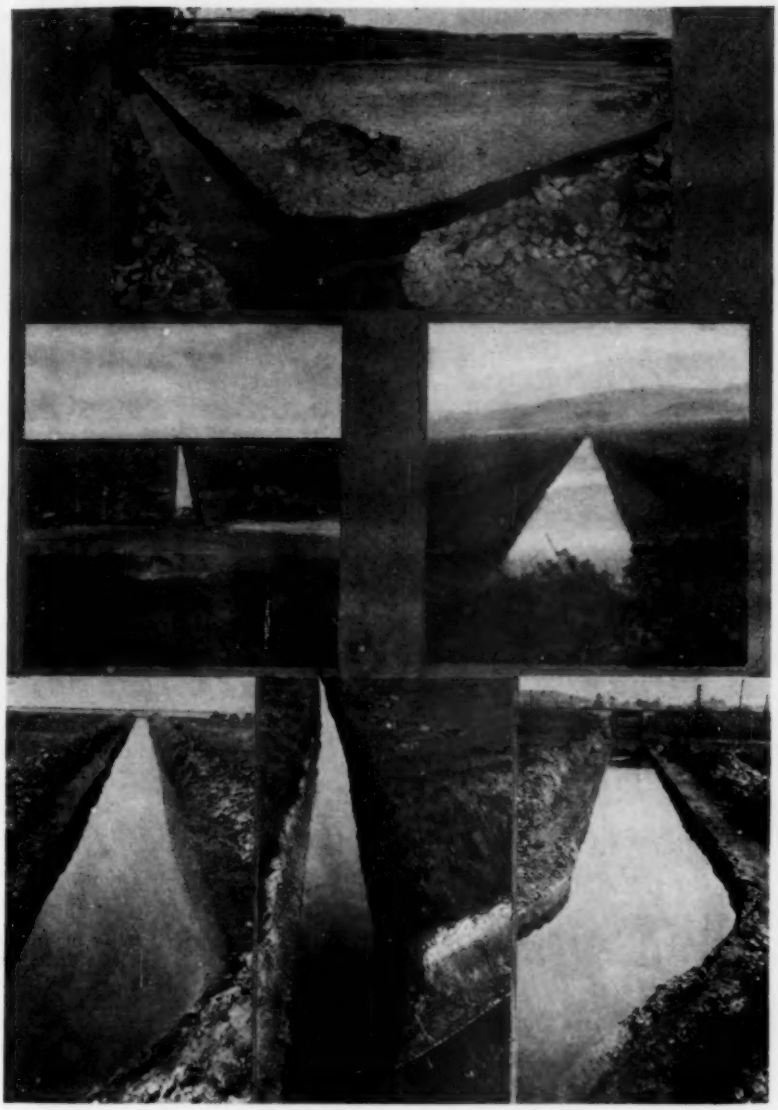

FIG. 117.—Showing salt marsh drainage ditches constructed with hand labor under the CWA. These marshes were prolific breeders of *Aedes squamiger* as early as January 15, followed by *Aedes dorsalis* in the early spring.

West Basin Project SLF-225 or 1046X—Los Angeles County.—There existed a large area at the head of the basin which was flooded at extreme high tides and also was the recipient of storm water drainage from nearby hills. A tide gate was installed and sufficient trenching was done to drain the entire area. The actual drainage has been accomplished, but a little more work is necessary to complete the project. It is now eighty per cent complete.

Project SLF-203 or 1042X—Spring Brook, Riverside County.—Clearing, channeling and filling of all mosquito breeding areas along Spring Brook and Tequesquite drain in the City of Riverside has proved to be a difficult task. The work has proceeded slowly, and at this time it is between 65 and 70 per cent complete.

Project SLF-192 or 1087X-Huntington Beach Project—Orange County.—Three separate salt marsh areas lying between Seal Beach and the Santa Ana River are included in this project. Open drainage of these salt marshes is to be done in an attempt to control the enormous broods of mosquitoes which take flight periodically during the summer months. The work was recently started and is 2 per cent complete.

TOOLS AND OTHER EQUIPMENT.—An inventory of equipment shows tools and equipment used on this project totaling $6,325.38. As already stated, a great deal of equipment was loaned to us earlier in our work by county C.W.A. directors, already organized mosquito abatement districts, and other agencies. Among the items on our inventory there are listed: axes, scythes, spades, saws, railroad picks, grub hoes, wheelbarrows, bush hooks, grass hooks, stone hooks, machetes, corn knives, mattocks, shovels (round-pointed and square-pointed), rakes, rubber boots, first aid kits, crow bars, splitting wedges, milk cans (for transporting top minnows), minnow sieves, buckets, metal tapes, hand levels, level rods, etc.

SUMMARY OF WORK DONE AND COSTS.—Although the administrative personnel, with two or three exceptions, remained the same throughout

SUMMARY OF MOSQUITO CONTROL OPERATIONS IN CALIFORNIA UNDER C. W. A.

December 15, 1933 to February 15, 1934

Area cleared	80.05 acres	Stream bank cleared	190,657 feet
Bulkhead constructed	718 feet	Culvert laid	12 feet
Ditches constructed	180,864 feet	Levee repaired	24 cubic yards
	24,563 cubic yards	Stream banks burned off	32,736 feet
Fill	7,484 cubic yards	Men employed	710
Sheet piling	1,030 feet	Labor cost	$39,146.98

February 16, 1934 to April 26, 1934

Area cleared	46.24 acres	Stream bank cleared	98,966 feet
Bulkhead constructed	376 feet	Culvert laid	110 feet
Ditches constructed	120,410 feet	Culvert repair	42 cubic yards
	16,363 cubic yards	Tide gate repair	44 cubic yards
Fill	1,655 cubic yards	Levee repair	205 cubic yards
Holes bored	28	Men employed	565
Slough cleared	1,415 feet	Labor cost	$26,917.20

the term of the project, the sponsorship, as already pointed out, changed from the U. S. Bureau of Entomology to the California State Department of Public Health; hence the summary of mosquito control operations under the CWA is divided into two parts: that done from December 15, (work actually began Dec. 29) 1933 to February 15, 1934, and that from February 16 to April 26, 1934. (work ended March 29).

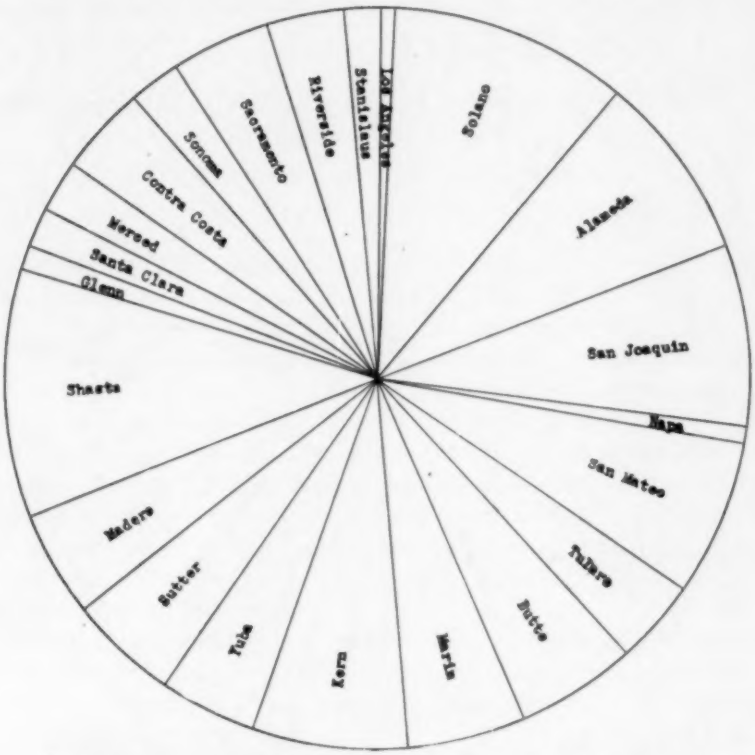

FIG. 118.—Graph showing relative portions of total amount expended on mosquito control in counties under the CWA plus funds donated by local authorities for the period Dec. 29, 1933 to Feb. 15, 1934.

Work was actually done on 46 projects in 22 counties ranging from Shasta to San Diego. A total of 301,274 feet (about fifty-seven miles) of drainage ditches were constructed with a total of 40,926 cubic yards of excavation, at a unit cost of $0.655 per cubic yard under the Federal and $0.889 per cubic yard under the State CWA; 289,623 feet of stream bank was cleared at a unit cost of $0.0329 per foot under the Federal and

$0.0495 per foot under the State CWA; also 126 acres of brushing; fills amounted to 9,109 cubic yards, at a unit cost of $0.413 per cubic yard under the Federal and $1.033 per cubic yard under the State CWA; levees, tide gates and culverts were repaired and placed. Thousands of top minnows (Gambusia) were distributed. Many potential breeding

FIG. 119.—Graph showing relative portions of total amount expended on mosquito control in counties under the CWA plus funds donated by local authorities for the period Feb. 16 to March 29, 1934.

places were eliminated, but in most instances work was done where larvae and pupae indicated points of attack. Fifteen species of mosquitoes were dealt with. The total cost of the project for the entire period from December 15, 1933 to April 26, 1934 was $87,298.96.

FINAL REPORT.—A comprehensive final written, and photographic report of the California Mosquito Control project was submitted to the State Civil Works Administration. This report contained regional and

organization charts, regional reports, work summaries and unit cost data, graphs, showing cumulative man-hours worked, ratios of man-hours used to man-hours allotted, graphs showing expenditures in the various counties, maps giving locations of control projects, and allocation of administrative cost and expenditure for tools, etc. A copy of this report together with copies of all individual projects with maps and other data are on deposit in our office and will be of great value should this work be carried forward at some future date.

THE OLFACTORY RESPONSES OF FLIES IN A NEW TYPE OF INSECT OLFACTOMETER[1]

I. Theory and Design of the Olfactometer

By W. M. HOSKINS and R. CRAIG

Recently two olfactometers have been designed for use with flying insects. Ripley and Hepburn (1929) in their studies with the Natal fruit fly, *Pterandus rosa* (Ksh.), used a cylindrical chamber with eight holes equally spaced around the wall. Each hole led to a tube through which air carrying an odor was drawn. Traps prevented the flies from returning to the main chamber. Circulation was maintained by withdrawing air through a hole in the bottom of the chamber. Illumination was centrally overhead. McIndoo (1933) used a wooden olfactometer with blowflies. It was a rectangular box with two perforated plates in the bottom several inches apart. Moist air was forced through one and air carrying an odor through the other. No forced ventilation from the box was provided. Illumination was from above.

Each of these machines has certain obvious disadvantages. That of Ripley and Hepburn is very slow in operation, many hours often being required for a single run. This slowness is largely due to the fact that each insect is allowed but a single decision. For this reason a great many insects must be used in order to minimize accidental responses. In McIndoo's instrument only a very small percentage of the population respond at all, and hence most of the insects used contribute nothing to the results. Certain other difficulties with each olfactometer will be mentioned below.

REQUIREMENTS FOR AN INSECT OLFACTOMETER.—An ideal insect olfactometer should satisfy at least the following requirements:

a) The environment should be as nearly normal as possible.

[1]Contribution from the laboratory of insect physiology and toxicology, Division of Entomology and Parasitology, University of California.

b) A large fraction of the individuals tested should respond.

c) The results should be attributable only to the chemical stimulus being studied.

d) Results should be obtainable within a short time.

e) Results should be obtainable with either a homogeneous or heterogeneous population.

Probably no environment during a test is entirely normal but minimum abnormality is very desirable for otherwise the results apply only to the particular conditions prevailing at the time of the test. For a similar reason it is desirable to provide a fixed temperature and humidity and to use insects of the same age and state of nutrition. Unless a large fraction of the individuals respond the results apply only to the fraction which does take part. This is the most serious objection to McIndoo's instrument. On page 613 of his article data are given showing that of about 300 Calliphora in the box an average of 2.6 responded at any given time to moist air and an average of 24.0 responded to the odor from sour milk. Similar results have been obtained in this laboratory with a McIndoo olfactometer. If much motion occurred to and from the perforated plates, this would not be a serious objection, but observations have shown that most of the flies remained motionless at different points within the box during the whole test.

If any other factor than the particular chemical stimulus enters into the final results, ambiguity cannot be avoided. This does not mean that every act of the insects must result from the chemical stimulus, but that all other effects must either be quantitatively allowed for, or cancel out automatically. For example, the effect of light gave trouble to Ripley and Hepburn (page 70) in their experiments with fruit flies. This point will be mentioned again in connection with the olfactometer designed in this laboratory. The necessity for obtaining results quickly holds particularly for insects which live but a short time or require food often. Exposure to an odor may lead to fatigue of the olfactory sense with resulting decline in response and a relative increase in the effect of other stimuli. One method of reducing the time necessary for the insects to make a choice is to place the standard and test regions close together as in the instrument described below. Repeated opportunity for choice is also of value for this reason. The olfactometer of Ripley and Hepburn does not do this, but allows each insect only a single decision. In their machine the only orienting influence (aside from the small effect of moving air) is the gradient in intensity of odor from each opening toward the central exhaust. This change in intensity along the stream of air is necessarily small and therefore the orienting influence is weak and the response slow

and less decisive. A similar situation exists in McIndoo's instrument. A maximum gradient in intensity of odor and consequently maximum orienting influence is afforded by placing the contrasting regions closely adjacent so that a very sharp gradient exists just between them. Except for the possibility of memory for an odor, the only condition in which a directed response is possible is when an organism is situated in a gradient in intensity of the odor.

A group of insects, each of which has an identical olfactory response to a particular substance, may be called homogeneous with respect to this stimulus. Similarly, if variations exist the group is heterogeneous. Of course, no group of insects is ever really homogeneous but this condition may be approximated by choosing individuals of the same age, size, sex, state of nutrition, etc. If a homogeneous population is placed in an instrument allowing each insect but a single decision; e.g., the Ripley and Hepburn olfactometer, the entire number will go to the more attractive or less repulsive region, provided no non-olfactory influence is present. It follows that with a homogeneous group of insects such an instrument can show only which of two odors is more attractive and quantitative measurement of the effect of differences in concentration is impossible. With a heterogeneous population such measurements may be made if sufficient variation in responsiveness exists. Ripley and Hepburn recognized this situation and attributed the presence of flies in the tubes with non-attractive odors to a "non-olfactory catch" which was brought about by light, moving air, etc.

On the other hand, the McIndoo instrument permits quantitative measurements to be made with either homogeneous or heterogeneous groups for it introduces a new factor; namely the average length of time an insect stays in the regions affected, and not affected, by the odors. This is measured by the number of individuals in the regions at intervals since the numbers present are inversely proportional to the time spent there. However, in McIndoo's instrument the response is very low because moving air is a poor attractant and brings but few individuals to the regions concerned and the phototropic effect of an overhead light tends to draw flies away from the bottom of the box. Also the standard and test regions are so far apart that rapid choice between them is impossible and the factor of duration of memory may enter into the situation.

Design of an Insect Olfactometer.—With the above mentioned considerations in mind, an olfactometer has been designed which is believed to embody most of the desired properties. It is shown in outline in Figure 120. The olfactometer proper, *A*, is a wooden box 12 inches long, 10

inches wide and 8 inches deep, painted dull black in the inside to prevent reflection of light and lined with glass to prevent the absorption and retention of odors. A screen cage, *B*, 9 by 9 by 9 inches containing the flies is placed within the box as indicated. When in use the box is covered with a light-tight, black, glass-lined top. A pump, not shown at the extreme right, forces air through the Y tube, *C*, from which the two streams pass through the flowmeters *D* and *D'*. These were calibrated by means of a Sargent Wet Test Meter and the air streams are regulated by means of screw clamps on the short rubber tubes between the glass Y tube and

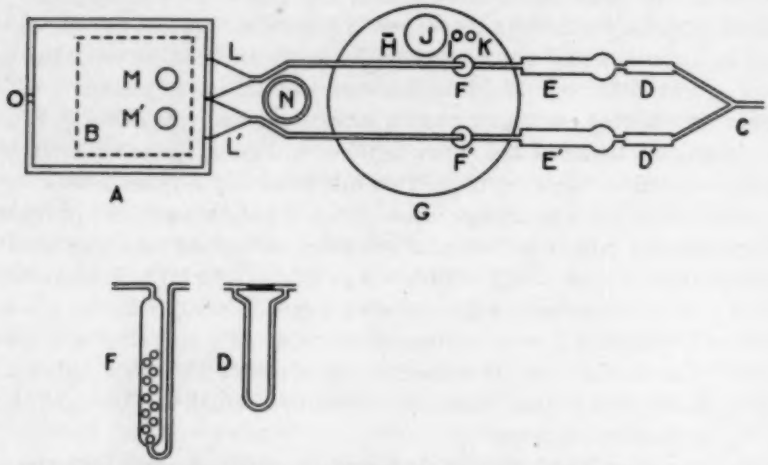

FIG. 120.—Diagram of the olfactometer and accessory apparatus. A, olfactometer; B, wire screen cage; C, Y tube; D and D′, flowmeters; E and E′, drying tubes; F and F′, saturating tubes; G, waterbath; H, electric heater; I, thermoregulator; J, stirrer; K, thermometer; L and L′, funnels; M and M′, exhaust holes; N, neon light; O, peephole.

the flowmeters so that air flows through the two lines at known and equal rates. If it is desired to dry the air, as when solutions in oil are being studied, two drying tubes, *E*, and *E'* filled with calcium chloride are inserted next. These can be omitted when aqueous solutions or the odors from plants, etc., are being studied. The air is then bubbled through saturating towers, F and F′. These are glass tubes 1 inch in diameter and 10 inches long, with inlet at the bottom and are filled with small glass beads. One contains a solution of the substance whose effect upon the olfactory sense is being studied. This solution is of known concentration in an appropriate solvent. When possible water is to be preferred, but oil-soluble substances may be dissolved in a high boiling, highly refined

petroleum oil. The other saturating tower contains the pure solvent. To ensure uniform volatility from the solutions the saturating towers are placed in a waterbath, *G*, which is equipped with an electric heater, *H*, a thermoregulator, *I*, a stirrer, *J*, and a thermometer, *K*. When solutions of varying concentration are being studied it is very important to ensure that the air upon emergence from the towers contains the solute in amount corresponding to its true volatility from the solutions. Accordingly, bubbling must not be too rapid and in some cases it has been found necessary to use an extra saturating tower in series with the first one.

From these towers the two streams of air pass into two 10 centimeter funnels, *L* and *L'*, which are fastened tightly over circular holes in the end of the olfactometer. The screen cage, *B*, is set directly against the rims of the funnels. The lowest points of these rims are set up 1½ inches from the bottom of the olfactometer. The two streams of air expand and move more slowly as they pass through the flaring funnels and out into the box. They are withdrawn through two exhaust holes, *M* and *M'*, in the bottom from which tubes lead to a suction pump. It has been found that by withdrawing air a little faster than it is introduced the major portion of the space within the olfactometer is kept free of odorous material and the factor of olfactory fatigue is kept at a minimum. Essentially, this arrangement provides two regions immediately adjacent to one another, between which the insects are to make a choice. Since the regions are close together, repeated choice within a short time is possible. It was found, as with the McIndoo instrument, that few blowflies respond if the only attractants are odor and moving air.

In order to bring a large percentage of the population to the desired regions a light, *N*, is placed behind the funnels. To ensure that the areas are equally illuminated runs should be made at frequent intervals with no odorous material in the air streams or with no air flow. The use of the phototropic response introduces no error with this type of olfactometer because the contrasted regions are very close together and freely accessible from each other. Results are based upon counts of the numbers of individuals upon the areas at chosen intervals so that the criteria of effect are the average periods spent on the areas. The possible objection to use of two different kinds of stimuli is of little importance because in normal environment flies are under the influence of many stimuli and it would be quite impossible to obtain an environment producing but a single type of stimulus. Furthermore, Crozier and Pincus (1927) have shown that with rats the responses to the stimuli of light and gravity are additive; i.e., the responses to the two types of stimuli are independent of each other. Therefore, it is reasonable to assume that in the

present case if the light intensities on the two areas are equal and rates of air flow are equal, any unequal distribution can be attributed solely to the difference in olfactory response. This use of light would not be permissible with either the Ripley and Hepburn or the McIndoo olfactometer because the standard and test regions are far apart and insects attracted to these regions by light might be held there in spite of an olfactory repulsion. Furthermore, if the lighted areas are far apart an equal phototropic attraction can be obtained only in the region which is equidistant from these areas.

A number of different kinds of light have been tried and the most satisfactory results obtained with a neon type so constructed that a large, uniform source was faced toward the funnels. A closely wound helix was found to function well. The color used was the shade of light blue found by Herms (unpublished data) to be very attractive to blowflies. Other advantages of this kind of light are its uniformity and low temperature of the source. Although the matter has not been thoroughly investigated the distance of the light from the mouths of the funnels does not appear to affect the distribution of the insects. Sunlight is also a very powerful attractant for these flies, but it varies greatly and is not dependable during all seasons of the year.

Flesh flies, *Lucilia sericata* (Meigen), of the same age (one to two days old) from larvae reared in the laboratory on fish heads (Michelbacher, Hoskins and Herms, 1932) have been used. As has been observed by other workers, flies respond less readily just after feeding. For this reason the procedure has been to use flies fed several hours previously. In groups of thirty to fifty the flies have been kept in the previously mentioned wire screen cages, *B*, in a rearing chamber at approximately 25° C. With minimum disturbance of the flies a cage was placed in the proper position in the olfactometer and the currents of air and the light turned on. Observations were made through the peephole, *O*, in the opposite end of the box at one minute intervals. Usually from five to ten observations were made. All measurements were made at room temperature which varied from 20° to 25° C.

Results.—To illustrate the type of results obtained, data will be given for two organic compounds which have been studied in connection with the problem of olfactory response and chemical composition. Figure 121 shows the results with secondary amyl mercaptan and methallyl thiocyanate of commercial purity dissolved at various concentrations in highly purified, high boiling petroleum oil. Response was calculated according to McIndoo's method; i.e., the number of individuals on an area divided by the total number on both areas gives the response to the

odor. Fifty per cent represents no effect. Less than fifty per cent indicates repellent action and more than fifty per cent indicates attraction. It will be noted from Figure 121 that an attraction shown for low concentrations of one substance changes to repulsion at higher concentrations. This is a common phenomenon in human olfactory response; e.g., with perfumes.

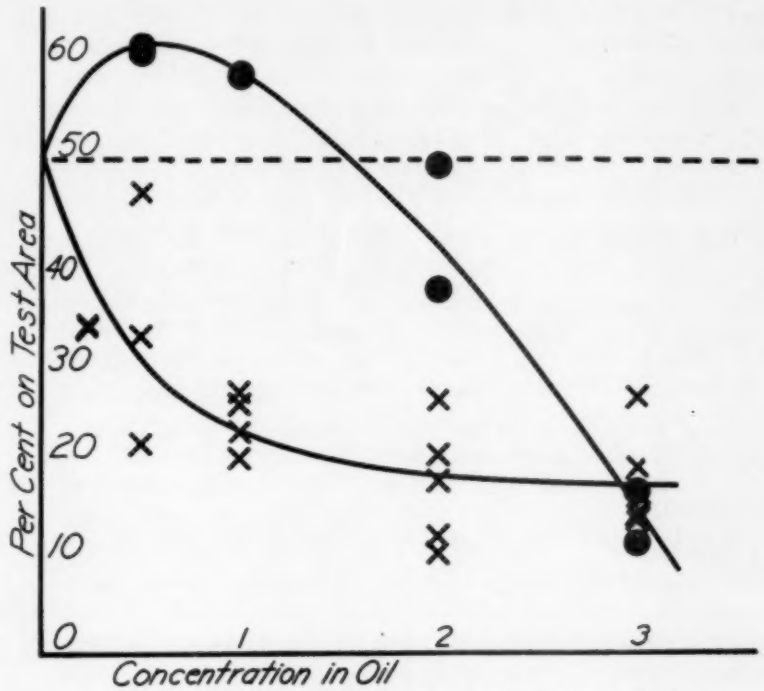

FIG. 121.—Relation of concentration of chemicals to olfactory response.

• = secondary amyl mercaptan. × = methallyl thiocyanate.

The effect of the oil solvent has been investigated. Air bubbled through a fresh sample taken from a closed metal container caused no olfactory response when compared with dry air. But after exposure to light and air for a few days a definite repellent effect developed. Hence the precaution was always taken to use solutions made from fresh oil. To illustrate the type of data secured the results of four runs are given in Table 1. These were all made in the manner described before except that in run 49 one of the saturator tubes contained several pieces of fresh beef heart. It will be noted that the total percentage responding was usually over

fifty per cent and that the separate observations of each run are consistent.

TABLE 1

Run No.	Substances compared	Total flies used	Numbers on areas						Totals	Per cent effect Attraction	Per cent effect Repulsion
49	air	30	9	8	5	7	6	7	42		
	beef heart		11	15	17	15	14	17	89	68	
61	oil	50	10	12	10	12	14	9	67		49+
	oil		9	13	13	10	13	10	68		
248	oil		16	20	24	21	18	—	99		
	methallyl	50									
	thiocyanate 1%		3	7	5	4	5	—	24		18
	oil		8	14	14	8	7	—	51		
264	Sec. amyl	50									
	mercaptan 1%		12	16	16	14	14	—	72	58	

It is a pleasure to express gratitude to Mr. S. C. Dorman of this Division for his assistance in carrying out many of the tests and in preparing the figures. The Shell Development has furnished the chemicals for testing and has given generous financial aid.

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RECENT DEVELOPMENTS OF THE VAPO DUST METHOD OF PEST CONTROL

By WILLIAM B. PARKER, *Entomologist, California Spray-Chemical Corporation*

Vapo Dust, our trade name for a concentrated fluid insecticide or fungicide, atomized, diluted and carried with air, is rapidly assuming a prominent place in several of our Pest Control Programs.

We developed this process several years ago but its successful and extensive use has been delayed pending the development of machines which are capable of applying these concentrated materials in an effective manner to trees, vines, and truck crops.

There are two methods of applying concentrated liquid insecticides, the Paint Gun and the Vapo Duster. The Paint Gun uses a relatively small amount of high pressure air in proportion to the oil—approximately 300 cubic feet to one gallon of material. It produces a dense fog of very

fine particles and unless present in large numbers these very fine particles have not enough volume to be effective on many insects.

The Vapo Dusters adjusted for Grape Leaf Hopper produce a light fog of generally larger particles than is found in a Paint Gun fog. They develop about 4000 cubic feet of air for each gallon of oil and the particles while small enough to float in the carrying air are large enough to bring down the adult hoppers that fly through it.

We first started with a spray nozzle in the end of a sulphur duster tube and from that we have developed the present machine, composed of four blowers special nozzles and operated by a 40 H.P. engine. While we have patent applications pending on certain features of this process and apparatus, our main interest is in insecticides.

These big machines were able to satisfactorily cover the largest prune trees in the Santa Clara Valley, last winter. They have also been adapted for work on grapes and trees in full foliage.

Vapo Dusters control pests very rapidly. Mr. Jack Flebut treated 67 acres of large prune trees for Brown Apricot Scale in one day. He handled all of the material himself and worked on three separate orchards which were some distance apart. Mr. Paul Driver, of Delano, California, covered 700 acres of grapes in six days with excellent results in Hopper control. This work was done on both Thompson Seedless and Alacante vines in full foliage.

It was at first believed that Vapo Dust could not be successfully applied except under conditions favorable to good dusting. Experience has shown, however, that a little wind is not objectionable and weather favorable to good spraying is also favorable for Vapo Dusting.

Both day and night work has proved effective and machines often operate with two shifts. The night work is very spectacular, particularly when the outfits are equipped with several spotlights. The enveloping fog lighted from the machine shows clearly against the dark sky and illustrates the very thorough coverage which is being obtained.

Transportation through the orchard or field is an important problem. In order to solve this, we conceived the idea of using airplaines and spent a lot of money and time developing the airplane Vapo Dust method—but after waiting two weeks for favorable weather to put on one test we laid aside the idea until we had completed the ground outfit.

Trucks with dual tires have been fairly successful but where heavy wet soil was encountered on the Mills Orchard Co., of Hamilton City, a track laying trailer pulled by a tractor was used. This machine operated regardless of soil conditions. In orchard work the machines travel between four and six miles per hour but in vineyards they sometimes drive

eight to ten miles per hour. They cannot cover as large an acreage in a day as the airplane but we are reminded of the old story of "The Hare and the Tortoise".

The present Vapo Dusters treat two rows of grapes but only one row of trees at a time. We expect, however, that the new ones will be larger and will be capable of treating two rows of trees at once. This will double the speed of treatment and approach the performance of the airplane.

Some work has been done with hand Vapo Dusters. This type of application will greatly extend the use of Vapo Dust, particularly on garden and truck crops.

MATERIAL.—Our first experimental work on Leaf Hoppers was done with oil and Pyrethrum, we then used pure oil but found that some toxic material was needed to finish off those insects only lightly hit.

Water mixtures or regular emulsions containing oil emulsified in the water where the water is the external phase, gives a partial water wetting and does not have the same oil wetting power as pure oil and they also evaporate so rapidly that they do not make a good base for Vapo Dust.

In considering the problem we were confronted with the desirability of combining the advantages of an oil wetting material with a moderate dilution which would afford a cheap harmless means of extending the material. In order to meet these requirements we have considered an innovation which, as far as we are aware, has never been successfully attempted. This is the use of *Water in Oil Emulsion*. In terms of the old established methods of application a Water in Oil Emulsion would not be practical, safe, or effective. Past efforts to apply pure oil with a regular spray nozzle have sooner or later caused serious injury. However, by our Vapo Dust Process all the advantages that we have realized in the use of straight oils are obtained with the Water in Oil Emulsion. The water dilutes the oil and the oil prevents the water from evaporating and gives the material an oil wetting rather than a water wetting effect. Water in Oil Emulsions have been made which contain as high as 75% water and these make it possible to use more material per acre, resulting in better coverage, less danger of oil drenching and still avoid the use of large quantities of water.

Lime and Sulphur Solution, Bordeaux Mixture, Copocil, Arsenate of Lead, Nicotine, Rotonone, Pyrethrum, etc. may be incorporated in either the oil or the water phase of this new type of insecticide. Preliminary experiments with all of these materials, alone and in combination have been conducted as a basis of our patent applications. They appear very promising as insecticides and fungicides.

INSECTS CONTROLLED WITH VAPO DUST.—Brown Apricot Scale and Red Mite eggs were attacked in a large way last winter on deciduous trees in the Santa Clara Valley. A couple of thousand acres of prunes and apricots were treated. With the exception of a few rows of trees, treated when the machines were not functioning properly, the control has been excellent.

We applied from ten to sixteen gallons of a special blend of Phytonomic oil per acre, depending on the size of the trees. The coverage was very complete and even as was evidenced by the uniformity of the bloom. This Winter Vapo Dust cost the growers 35c per gallon and application $1.75 per acre.

When Thrips on prunes and nectarines appeared some work was done on them. Pyrethrum and a light phytonomic oil, made originally for the Grape Leaf Hopper work, was applied at the rate of six or seven gallons per acre and proved very effective on both the adult Thrips and larvae. It also killed any Canker worm and Leaf Roller larvae that were present.

Nicotine was also tested and proved effective on the Thrips. Lime Sulphur in oil gave a nice control of Pear Leaf Blister Mite and even the straight oil, where heavily applied, gave good control.

The Grape Leaf Hopper campaign has been very successful, not only against the over-wintering brood but against the first brood of nymphs, which appeared after the vines were in full leaf. The cost has been very reasonable. The prevailing price for Vapo Dust for Grape Leaf Hopper is 52c per gallon. We applied 3½ to 4 gallons per acre on the over-wintering brood and from 4 to 5 gallons per acre on the nymphs in heavy foliaged vines. The cost of application was $1.00 to $1.50 per acre depending whether the vines were treated from one or two sides.

We find that Vapo Dust applied with a Bean Vapo Duster, when operated to give the proper sized particles, kills over 95% of nymphs and adults on grapes in full foliage. One enthusiastic grower remarked that we did not kill 99% but we killed at least 98¾%.

Around 1600 gallons of Vapo Dust was applied to peas for Serpentine Leaf Miner. A large per cent of the adult insects were destroyed but the egg laying and subsequent development was so rapid that the plants were soon badly re-infested. The process worked very well and several properly timed applications might prove of value.

Our machinery development is sufficiently complete so that we are now ready to work on Pea Aphis and Melon Aphis and hope to extend the use of Vapo Dust to the truck growing areas.

This Vapo Dust process has several advantages over the old methods. A large area can be rapidly covered with a small amount of very toxic

material. The insects are not only contacted on the vine but most of the active forms are blown out into the enveloping fog where they are very completely wet. In fact, this process literally blows the bugs off their roost and then shoots them in the pants.

AIRPLANE VAPOR SPRAYING: A PROGRESS REPORT

By FRANK B. HERBERT, *Entomologist, Balfour, Guthrie & Co. Ltd., San Francisco, Calif.*

Since reporting upon airplane spraying a year ago[1], we have treated several thousand acres with very satisfactory results. This is now established as a reliable method of treatment with many advantages. Naturally, with the treatment of several thousand acres we have gathered data which will be used to advantage in future work.

WINTER OIL ON PRUNES AND APRICOTS.—Over three thousand acres of prunes and apricots were treated from the air for the control of brown apricot scale and oblique banded leaf roller using soluble oils without water dilution. These received an average of ten gallons per acre.

The results were very satisfactory giving a good scale clean-up on 95 per cent of the orchards, which is a high percentage for any type of treatment. In many of these orchards it is almost impossible to find a live scale, while similar unsprayed orchards are badly infested.

Stimulation from oil sprays which has been noted previously on prunes was also quite evident from the airplane treatments. In fact, the largest crops of prunes this season are on the orchards and parts of orchards so treated.

Most of this work was done in the Santa Clara Valley, keeping one plane busy from January fourth until blossom time. Apparently this coming season two or more planes will be necessary for this same district.

With the treatment for leaf rollers the plane was fully as satisfactory as ground treatments. In both cases it is essential that the work be done in the late dormant period.

As stated above a few orchards showed poor results. Most of these can be diagnosed as due to too low a dosage or too much wind. Individual trees showed poor results on account of the proximity of power lines or large shade trees.

The plane does not cover the larger limbs heavily enough for the control of moss or Italian pear Scale, but this service was not sold with that

[1]Frank B. Herbert. Airplane Liquid Spraying. Jr. Econ. Ent. Vol. 26, No. 6. Dec. 1933 pp. 1052–56. Illus.

in view. This is also true of the average dosage of oil applied with a ground rig. Where these pests are prevalent, we are recommending a heavier dosage of oil and caustic soda to be applied by ground machines to the scaffold of the trees once every three or four years. This dosage is heavier than probably would be recommended for application on the twigs or buds.

All winter oil sprays showed some tip injury during the past season whether applied from the ground or air. The injury from plane application was no greater than from the ground. Some of this tip injury can also be found where no treatment was made. This is apparently due to the fact that we had a mild winter which did not properly harden up the tip growth.

Apricots and Almonds.—A fungicidal oil was also used on apricots and almonds for the control of shot hole fungus and brown rot as well as scale and leaf rollers.

In the spring treatment of part of this acreage, the oil contained lead arsenate for twig borer control. This control was more satisfactory than the ground treatments.

Peaches and Nectarines.—Over three thousand acres of peaches and nectarines were treated with oil by plane during the past season. Part of this acreage received a fungicidal oil in the fall for the control of peach blight, part received a delayed dormant treatment of fungicidal oil containing arsenate of lead for the control of leaf curl and twig borers, while part that had already received a fall fungicide, received no fungicide in the spring but instead an oil containing lead arsenate for twig borers only. This last was applied after foliage appeared in the spring and soon after the first wilting twigs showed that worms were entering. This time of treatment has proved very efficient in worm control. All peaches received about six gallons per acre.

The results from these treatments are satisfactory and will undoubtedly result in an increased acreage next season. Some orchards which received one fungicidal oil treatment last season should have had both a fall and spring application.

Grapes.—Some two thousand acres of grapes were sprayed this season by plane for control of grape leaf hoppers, at an average of four gallons per acre. The undercoverage of heavy foliage was not great enough to kill a high percentage of the young hoppers, but the kill of adults in the spring before the foliage is too heavy has proved highly satisfactory. Where heavily foliaged vines are trellised it has been found essential to parallel the rows rather than to fly across them.

TRUCK CROPS.—Very little has been done on truck crops or other low growing crops since last reporting, but there are a number of pests which we believe can best be treated by liquid rather than dust. This phase of the work looks promising and will be followed up.

EQUIPMENT.—More than sixty-five thousand gallons of the concentrate soluble oil sprays were applied during the 1933–34 season by two types of plane equipment. Both have proved satisfactory with very little change. Some of the equipment has been made sturdier, and finer atomization has proved the most satisfactory.

Greater experience has been obtained as to dosage, weather conditions, etc. Filling pumps have been made larger and faster so that less time is wasted on the ground.

One plane is now equipped with four "rotors" instead of two, which has increased its acreage capacity by fifty per cent.

SPEED RECORD.—Four hundred and forty acres were treated in one day by one plane, putting on some 2650 gallons of oil. This same plane treated one thousand acres of peaches in two days and two hours, the fastest that such an acreage has ever been treated with liquid. Of course this called for proper weather conditions all day long which are not often available.

CONCLUSIONS.—Airplane application of oil sprays has proved to be fast, efficient and economical. It will not replace all other methods of treatment but it undoubtedly has a rosy future.

FUMIGATION EXPERIMENTS WITH THE CALIFORNIA RED SCALE UNDER ORCHARD CONDITIONS

By WILLIAM MOORE,* *Owl Fumigating Corporation, Azusa, Calif.*

Under controlled conditions in the laboratory (4) it was found that temperature and relative humidity influenced the results of fumigation of the California Red Scale, *Aonidiella aurantii* Mask., from certain areas. During the past season, a series of field experiments have been conducted in orchards at Corona, Glendora, No. Whittier Heights, La Habra, Fullerton, Yorba Linda and El Modena. These districts are all considered as areas in which the red scale is very difficult to kill. The experiments were carried out to determine the effectiveness of the regular 100% dosage of hydrocyanic acid under different climatic conditions.

*The writer wishes to express his thanks to the work of J. A. McDonough, Harold Orde and Robert Wathen in carrying out the numerous field tests and the counting of millions of red scales in determining the kills.

In these tests, only trees which had not been exposed to drift gas were fumigated since Gray and Kirkpatrick (2) have shown drift gas to be a complicating factor.

METHODS USED IN WORK.—Each fumigation consisted of a set of five trees. The trees were covered with the tents, measured and dosage determined for each. The hydrocyanic acid was then applied to all the tents so that the exposure was simultaneous. All exposures were for a period of 45 minutes.

The temperature and relative humidity in the orchard were recorded on a hygro-thermograph from the morning preceding the fumigation until noon of the day following the fumigation. Sling psychrometer readings were frequently made during the day preceding the fumigation and always at the beginning and close of each fumigation. Soil temperatures were taken on the Northeast and Southwest sides of a tree at the time of the fumigation. The temperature was taken of a lemon from the Northeast and one from the Southwest side of the tree preceding the fumigation. The direction and, in many cases, the rate of the air drift was determined.

The day following the fumigation approximately 20 lemons were collected from various parts of each fumigated tree and kept in a cool room 43°–55°F until the scale count was made. Lemons were collected from untreated trees and handled in the same manner to serve for the determination of the natural mortality. The natural mortality was determined from a count of approximately 5000 insects and the results of a treatment from a total count of about 15,000 insects from the five trees.

The significance of the means was determined by Fisher's Method (1) for unpaired samples and by Love's Modification of Students Method (3) for paired samples. With the unpaired samples, the odds recorded are the odds against so great a difference due to chance and in the paired samples, the odds are that the one result is better than the other.

THE TOLERANCE OF THE RED SCALE TO HYDROCYANIC ACID.—The first question to be answered is whether poor fumigation results can be attributed to a built up tolerance of the red scale to hydrocyanic acid. Table 1 gives results obtained at different times in four orchards. If the insects have developed a tolerance to hydrocyanic acid, one would expect poor results regularly. Whether the fumigation was conducted one month or the next should make little difference in the kill. At no time should one obtain high kills such as 99–100% after deducting the natural mortality. Such, however, is not the case. The kill may be high or low, not only a few weeks apart, but even on the same night as at Yorba Linda, where at one time a kill of 69.35% was obtained and in the next

hour, a kill of 99.40%. If the insects were tolerant when the kill of 69.35% was obtained, then increasing the dosage at that time should have resulted in an increase in the kill. It so happened that in that particular set, 10 tents were used, 5 were treated with 100% schedule, giving a kill of 69.35% and 5 were treated with 122% giving a kill of 32.23%.

TABLE 1. KILLS OBTAINED IN FOUR ORCHARDS IN DIFFERENT FUMIGATIONS WITH 100% DOSAGE OF HYDROCYANIC ACID

Corona		Glendora		La Habra		Yorba Linda	
Date	Kill	Date	Kill	Date	Kill	Date	Kill
June 15	99.55%	July 24	97.67%	Oct. 24	99.72%	Nov. 23	99.41%
July 10	92.92%	Aug. 7	99.69%	Nov. 3	99.12%	Nov. 23	95.86%
July 10	97.03%	Aug. 24	98.08%	Nov. 13	87.08%	Nov. 23	69.35%
July 19	96.04%	Nov. 6	99.04%			Nov. 23	99.40%
Aug. 2	99.08%	Nov. 6	97.96%				
Nov. 20	100.00%	Nov. 10	95.11%				
Dec. 5	97.75%	Dec. 1	97.90%				
Dec. 12	99.87%	Dec. 18	99.62%				
Dec. 19	88.19%						
Jan. 9	99.76%						

If these results are due to a built up tolerance of the scale, it is extremely variable. An explanation on the basis of tolerance would require that the insects on the trees of one row are decidedly tolerant (69.35%) while on the next row, they are not tolerant (99.40%) or the tolerance is capable of being changed between 7.58 P. M. and 9.14 P. M. on the same night. On the other hand, it would appear more reasonable to consider that the difference in kill may be due to climatic conditions, methods of application or to variations in the concentrations of hydrocyanic acid to which the insects are exposed.

INFLUENCE OF TEMPERATURE AND RELATIVE HUMIDITY.—In the present series of tests, two distinct seasons are arbitrarily selected. The period May 23–Nov. 1 is considered as the summer season. During this period temperatures are usually high and relative humidities low during the day but at night time, the temperature drops rapidly and the relative humidity increases. Most nights in this period will have relative humidities above 90% and many reach the dew point. The weather is largely influenced by sea breezes. During the second period, Nov. 1–February 15, rains occur and following the rains, land breezes from the desert produce very low humidities both day and night. Records from Nov. 1 to Feb. 15 inclusive at the laboratory at Azusa showed 33.7% of the nights with the relative humidities below 50% and 36.4% of the nights with the relative humidity above 90%. Even a very short distance makes considerable difference in both temperature and relative humidity. Work in an orchard at 60% to 80% relative humidity may be done

TABLE 2. RESULTS OF FUMIGATION DURING THE SUMMER SEASON

Temp. / Rel. hum.	50.1–55°		55.1–60°		60.1–65°		65.1–70°		70.1–75°		75.1–80°		Atomizer Averages
	Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser	
90.1 to 100%	99.83C 98.34C 99.44H		99.34C 98.54C										99.10%
80.1 to 90%	99.70G		98.75F 99.08C 99.95G 99.01F 98.85F 98.52F 98.54F 99.33H		97.93F 95.43F 99.00C 97.40F 98.75F 97.12F 98.34G		97.83F 96.27F 99.51F 99.47C						98.44%
70.1 to 80%					99.39F 99.51C 99.59G 98.69F 99.46C 97.58C		96.06C 96.04C 93.24F 98.08G		98.79C				97.87%
60.1 to 70%			99.33F 99.44G 99.43H	99.15G 99.76H	97.03C 98.99C 98.35G 98.04G 98.11F	99.23G 99.01G 99.49H	99.83C 99.00C 98.39G	99.11G	97.98C 93.39G 98.03G		97.67G		98.20%
50.1–60%					99.27F		99.48F	99.27F	98.98C				99.25%
40.1–50%			96.93C	99.58C	98.82G				98.35C				97.95%
30.1–40%					96.79G	99.44C			92.92C				94.86%
20.1–30%													
10.1–20%										99.62G			
AVGS Atomizer	99.33%		98.93%		98.27%		97.76%		96.92%		97.67%		
AVGS Diffuser				99.55%		99.29%		99.19%		99.62%			

Fumigations between May 23, 1933 and Nov. 1, 1933

TABLE 3. RESULTS OF FUMIGATIONS

Temp. / Rel. hum.	40.1–45°		45.1–50°		50.1–55°		55.1–60°	
	Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser
90.1 to 100%			100.00C 99.96C	99.21C 100.00C				
80.1 to 90%				96.76G 97.90G	99.12H	99.87C		
70.1 to 80%			97.88C 98.02G	99.29C 98.10G	99.19H 99.68M 99.62C	99.87C 99.36M	98.99C	99.10C 99.59M 100.00C
60.1 to 70%	94.29C				99.61G			
50.1 to 60%	99.36C	99.76C 96.92C		98.92M				
40.1 to 50%		98.69C	97.84C		98.10G	99.62G	97.78M	99.62C 99.14M
30.1 to 40%				98.31C	99.60C	99.13C 98.13C	95.23Y 97.96G 98.78W	98.93G 99.04G 97.03W 98.62W
20.1 to 30%					97.75C	100.00C		
10.1 to 20%								
AVGS Atomizer	96.82%		98.74%		99.08%		97.75%	
AVGS Diffuser		98.46%		98.56%		99.42%		99.01%

Fumigations between Nov. 1,

while at the same time, within five miles, the trees may be wet from heavy fogs.

Table 2 gives the fumigation kills between May 23–Nov. 1 arranged according to temperature and relative humidity. The work was carried out with a pump atomizing liquid hydrocyanic acid under the tent and with a Diffuser in which the liquid is passed through heated coils to volatilize the hydrocyanic acid. The letters following the percentages indicate the location of the tests. C = Corona; F = Fullerton; G = Glendora; H = La Habra; W = No. Whittier Heights. Comparatively few fumigations were made with the Diffuser during this period since this applicator is generally used for winter work. It will be noted that with the atomizer, the kills decrease with an increasing temperature. Considering only those ranges where there are a fair number of tests, we find the following differences:

Temp.	Kill	Temp.	Kill	Difference	Odds
55.1°–60°	98.93%	60.1–65°	98.27%	0.66%	20 to 1
55.1°–60°	98.93%	65.1–70°	97.76%	1.17%	75 to 1
55.1°–60°	98.93%	70.1–75°	96.92%	2.01%	75 to 1
55.1°–65°	98.53%	65.1–75°	97.47%	1.06%	67 to 1

DURING THE WINTER SEASON

60.1–65°		65.1–70°		70.1–75°		75.1–80°		Averages	
Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser	Atomizer	Diffuser
								99.98%	99.60%
								99.12%	98.18%
	99.85C								
								98.90%	99.39%
98.51H	99.51H								
	99.93C								
	98.63C							97.47%	99.36%
	99.93C								
								99.36%	98.88%
								97.91%	99.27%
								97.89%	98.45%
	99.84Y		99.84Y						
			95.11G					97.75%	98.45%
99.11Y	99.96Y	87.08H		89.28H	99.40Y	95.86Y	99.41Y		
		69.35Y						88.14%	99.59%
98.81%		78.21%		89.28%		95.86%			
	99.66%		97.47%		99.40%		99.41%		

1933 and Feb. 14, 1934

Using Fisher's Method odds of over 19 to 1 are considered significant.

Although the Diffuser was used only a few times during the period covered by Table 2, it is interesting to note that in these few tests there was no temperature effect.

There was no relationship between the relative humidity and the kill as represented by averages for the atomizer across Table 2. There was a decided drop in the kills below 40% but the number of tests was not sufficient to give these figures any significance.

Table 3 gives a set-up of the fumigations between Nov. 1, 1933 and February 15, 1934. It will be noted that the conditions of temperature and relative humidity encountered during this period are quite different from those in the summer period. The soil may be wet or dry and its temperature may be lower than the air temperature even during night fumigations, the reverse of summer work when the soil temperature at night is always higher than the air temperature. Under very dry conditions, the lemon temperature may also be decidedly lower than the air temperature. With all these new variables, the temperature relationships disappear and results are erratic.

Hydrocyanic acid applied with the atomizer at low relative humidities gave poorer kills than at high relative humidities. There are 13 tests with above 50% relative humidity and 13 tests below 50% relative humidity. The average kill for those above 50% relative humidity is 98.79% and for those below 50% 94.13%, a difference of 4.66% with odds of 10 to 1. One figure, 69.35% is abnormally low compared with the others and if this is removed, the comparison becomes 98.79% to 96.20% a difference of 2.59% with significant odds of 23 to 1.

People familiar with citrus fumigation may consider the difference as due to tighter tents caused by moisture condensing on them at the higher relative humidity. If this were the explanation, the same results should be obtained with the hydrocyanic acid applied with the Diffuser. Twenty tests with the Diffuser above 50% relative humidity gave an average kill of 99.12%, 18 tests below 50% relative humidity had an average kill of 98.88%, an insignificant difference of the two sets of 0.23%.

Under dry conditions, the soil temperature is nearly the same as the air or even lower, whereas, under humid conditions, the soil temperatures are generally higher than the air temperatures. Table 4 gives the air-

TABLE 4. AIR-SOIL TEMPERATURE RELATIONSHIP ABOVE AND BELOW 50% RELATIVE HUMIDITY TREATMENT WITH THE ATOMIZER

Above 50% relative humidity				Below 50% relative humidity			
Kill	Air temp.	Soil temp.	Diff.	Kill	Air temp.	Soil temp.	Diff.
100.00%	49°	58.5°	+ 9.5	99.60%	54°	56 –60°	+2°+6°
99.96	47	57.5	+10.5	99.11	63	61.5–64	—1.5+1
99.68	50.5	57 –60.5	+ 7.5+10	98.78	56.5	57	+0.5
99.62	55	56 –59	+ 1 + 4	98.10	52	48 –48.5	—4 —4.5
99.61	54	57.5–60	+ 3.5+ 6	97.69	56	57.5–59	+1.5+3
99.36	42	45.5	+ 3.5	97.84	47	51.5	+4.5
99.19	54	67 –68.5	+13 +14.5	97.78	58.5	62.5–65	+4 +6.5
99.12	52	64.5	+12.5	97.75	51	47.5–48	—3 —3.5
98.99	58	64 –65	+ 6 + 7	95.86	76	71 –81	—5 +5
98.51	61	71 –74	+10 +13	95.23	56	61 –62	+5 +6
98.02	50	55.5–56.5	+ 5.5+ 6.5	89.28	73	71 –73.5	—2 +0.5
97.88	49	50	+ 1 + 1	87.08	69	68 –71.5	—1 +2.5
94.29	44	47	+ 3	69.35	69	70 –73	+1 +4

soil temperature relations for these experiments. In some cases, under dry conditions, sudden changes in temperature throw these relationships completely out. In the case of the 69.35% kill under 50% relative humidity, the air temperature was 69° at the start and within a few minutes, was 74°. The soil was slowly cooling due to evaporation caused by the low relative humidity. At the close of this fumigation period, the air temperature was 72° and the soil 64–68° F. The air-soil temperatures cannot be compared too closely since the different readings will be obtained at different points under the same tree. The general conclusion

may be reached that under low relative humidities, the soil temperatures are nearly the same as the air temperatures or even lower. Under these conditions, the diffusion of the gas produced by the evaporation of the atomized liquid hydrocyanic acid under the tent is poor and results in a lower kill. When the hydrocyanic acid is applied as a gas and properly diffused the differences between the kills obtained at relative humidities below and above 50% disappear.

MISCELLANEOUS FACTORS WHICH MIGHT INFLUENCE THE KILL.—In addition to temperature and relative humidity, various other factors were considered that might affect the kill. The kill obtained in work done under normal fumigation conditions were not decidedly influenced by the following factors:

Place
Date
Time
Fall in temperature during the fumigation
Temperature of the lemon
Maximum day temperature preceding the fumigation
Time when max. day temperature was reached
Minimum relative humidity during day preceding fumigation
Hours below 40% rel. humidity preceding the fumigation
Minimum night temperature
Minimum temperature within 4 hours of the fumigation
Direction of air movements
Whether dew was deposited the night of the fumigation
Hours until dew was formed

A drop in temperature during the fumigation and the formation of dew soon after the fumigation appear to be favorable factors. One may obtain good kills when no dew forms such as a 99.40% kill when the relative humidity did not exceed 20% during the entire night. A falling air temperature makes the air-soil temperature relationship favorable for the diffusing of the gas produced by the evaporation of the liquid hydrocyanic acid applied with the atomizer.

The influence of air movements is difficult to determine. At times, strong puffs of wind occur which sway and bulge the tents, interspersed with periods of calm. At other times, there is a steady air drift which produces no tent movement. At this time no conclusion can be reached as to the limits of air movement permissible in good fumigation.

INFLUENCE OF THE METHOD OF APPLICATIÓN.—A few field experiments reported in a previous paper (4) indicated no significant differences between fumigations in which the hydrocyanic acid was applied as an atomized liquid or as a gas. With the large number of experiments re-

TABLE 5. PAIRED COMPARISONS OF THE ATOMIZER AND THE DIFFUSER

Location	Date	Temp.	Soil temp.	Rel. hum.	A Kill with diffuser	B Kill with atomizer	A–B
Bastanchury	May 23/33	66.5°	68–71°	55%	99.27%	99.48%	— .21
Glendora	Sept. 20/33	62	72–72.5	69	99.01	98.35	+ .66
La Habra	Oct. 16/33	60	68	63	99.76	99.43	+ .33
Corona	Oct. 18/33	60	65–67	44	99.58	96.93	+2.64
La Habra	Oct. 24/33	59	70–74	86	99.73	99.33	+ .40
Corona	Oct. 30/33	59	64.5–65	78	96.08	96.84	— .76
La Habra	Nov. 3/33	61	71–74	64	99.51	98.51	+1.00
Glendora	Nov. 6/33	56	57.5–59	31	99.04	97.96	+1.08
Corona	Nov. 9/33	54	56–60	38	99.13	99.60	—0.47
Yorba Linda	Nov. 14/33	63	61.5–64	18	99.96	99.11	+ .85
Corona	Nov. 20/33	49	58.5–58.5	93	99.21	100.00	— .79
Corona	Nov. 20/33	47	57.5–57.5	93	100.00	99.96	+ .04
Yorba Linda	Nov. 23/33	46	71–81	14	99.41	95.86	+3.55
Corona	Dec. 5/33	51	47.5–48	29	100.00	97.75	+2.25
Glendora	Dec. 18/33	52	48.5–48	46	99.62	98.10	+1.52
Corona	Dec. 19/33	44	47–47	64	94.51	94.29	+ .22
Corona	Jan. 9/34	42	45.5–45.5	55	99.76	99.36	+ .40
El Modeno	Jan. 17/34	58.5	62.5–65	47.5	99.14	97.78	+1.36
Corona	Jan. 22/34	49	50	71	99.29	97.88	+1.41
El Modeno	Jan. 24/34	50.5	57–60.5	74.5	99.36	99.68	— .32
Glendora	Jan. 29/34	50	55.5–56.5	74	98.10	98.02	+ .08
Corona	Feb. 14/34	55	56–59	76	99.87	99.62	+ .25
No. Whittier Heights	Feb. 12/34	56.5	57–57	41	98.62	98.78	— .16
Average							+ .67

corded in Table 2 and Table 3 better comparisons can be made. These tables show 86 fumigations with the atomizer. In these fumigations, 423 trees were used and over a million insects counted. They represent different climatic conditions encountered between May and February inclusive. The average kill for the hydrocyanic acid applied with the atomizer was 97.69%. A similar summing up of Diffuser tests show 49 fumigations covering 245 trees and a count of over 600,000 insects. The average kill was 99.10%. The difference in the kills obtained by the use of the atomizer and the Diffuser is 1.41% with odds of 97 to 1 in favor of the Diffuser. In these experiments, the majority of the fumigations with the atomizer were conducted under favorable summer conditions. Under conditions unfavorable to the atomizer, the differences are greater.

The 13 tests with the atomizer under winter conditions with the relative humidity below 50% gave an average kill of 94.13% while 18 tests with the Diffuser under similar conditions gave a kill of 98.88%. The difference is 4.75% with odds of 39 to 1, in favor of the Diffuser.

The best comparison would naturally be where the fumigations with the atomizer and the Diffuser were carried out simultaneously giving paired experiments. Twenty-three such paired tests were made, Table 5. The average difference in favor of the Diffuser was .67% with odds of 302 to 1 that the Diffuser was better than the atomizer. The difference is small but the advantage of the Diffuser is in a more consistent kill. The Diffuser gave above 99% kills in 19 out of 23 tests while the atomizer had only 10 out of 23 tests. These tests were made under a wide range of conditions and in only two tests was the atomizer at a particular disadvantage due to the soil being lower in temperature than the air. All comparisons were night fumigations.

Stages of Insects Surviving Fumigation.—In a series of experiments, the stages of development of the insects were determined in the counts made for natural mortality and for the results of the fumigation. From these data, the per cent kill of the different stages could be determined. Table 6 gives the results for the atomizer and Table 7 for the Diffuser. When high kills are obtained the survivors are all in or near the second molt. Lower kills are not due alone to an increasing number of survivors in this stage but to appearance of survivors in other stages of development. Poor kills are not due to larger percentages of the insects being in or near the second molt.

TABLE 6. KILLS OF VARIOUS STAGES OF THE RED SCALE IN FUMIGATIONS IN WHICH THE HYDROCYANIC ACID WAS APPLIED WITH THE ATOMIZER

Expt. No.	Temp. °F	Rel. hum. %	Dosage %	1st Instar	1st molt	2nd instar	2nd molt	End 2nd molt	Early gray	Late gray	Mature adult	Overall kill
108	53.0	37.0	122	100	100	100	100	99.5	100	100	100	99.90
"	47.0	47.0	"	"	"	"	"	99.0	"	"	"	99.80
118	50.5	74.5	100	"	"	"	99.4	99.3	"	"	"	99.68
119	54.0	70.0	"	"	"	"	98.8	99.5	"	"	99.8	99.61
115	42.0	55.0	"	"	"	98.7	99.7	98.2	98.8	"	99.7	99.36
107	46.5	82.5	122	"	"	99.0	99.0	97.3	100	"	100	99.13
117	58.0	72.0	100	"	"	100	100	97.2	99.3	99.1	99.6	98.99
111	52.0	46.0	"	"	"	"	75.7	91.3	100	100	99.2	98.10
119	50.0	74.0	"	"	"	98.2	97.5	98.2	96.8	97.5	98.6	98.02
117	49.0	71.0	"	"	"	"	98.4	87.7	97.8	99.0	96.0	97.88
108	47.0	47.0	"	"	"	96.8	96.0	96.7	100	100	97.8	97.84
116	58.5	47.5	"	"	"	100	96.8	93.5	"	"	99.2	97.78
108	51.0	29.0	"	"	"	"	98.7	92.5	95.8	"	98.8	97.75
106	76.0	14.0	"	"	"	98.2	89.2	89.4	96.2	97.1	96.9	95.86
112	44.0	64.0	"	"	"	100	96.5	94.0	89.6	87.2	83.9	94.29
106	69.0	15.0	"	"	90.3	78.0	51.1	32.1	50.0	68.4	88.4	69.35
"	69.0	15.0	122	96.8	64.3	40.0	14.1	0.0	0.0	16.6	55.8	32.23
Averages.....				99.81	97.33	94.64	88.88	86.20	89.66	92.05	94.92	

TABLE 7. KILLS OF VARIOUS STAGES OF THE RED SCALE IN FUMIGATIONS IN WHICH THE HYDROCYANIC ACID WAS APPLIED WITH THE DIFFUSER

Expt. No.	Temp. °F	Rel. hum. %	Dosage %	1st Instar	1st Molt	2nd Instar	2nd molt	End 2nd molt	Early gray	Late gray	Mature adult	Overall kill
110	63.0	60.0	100	100	100	100	100	99.8	100	100	100	99.93
"	63.0	67.0	"	"	"	"	"	99.8	"	"	"	99.93
"	55.0	88.0	"	"	"	"	99.7	99.8	"	"	"	99.87
"	61.5	72.0	"	"	"	"	100	99.6	"	"	"	99.85
115	42.0	55.0	"	"	"	"	"	98.9	"	"	"	99.76
111	52.0	46.0	"	"	"	"	97.3	93.0	"	"	98.6	99.62
113	55.5	79.0	"	"	"	"	100	99.1	92.8	"	99.3	99.59
116	48.0	60.0	122	"	"	"	"	99.5	97.7	98.5	99.5	99.54
106	76.0	14.0	100	"	"	"	98.8	100	100	97.4	99.4	99.41
"	71.0	11.0	"	"	"	"	97.5	98.1	"	100	99.7	99.40
118	50.5	74.5	"	"	"	"	99.0	99.6	99.2	99.0	99.2	99.36
117	49.0	71.0	"	"	"	"	100	99.6	99.6	99.3	98.5	99.29
106	71.0	11.0	122	"	"	"	"	98.4	97.1	97.9	99.3	99.25
108	50.0	33.0	"	96.0	"	99.0	95.0	99.5	99.1	100	100	99.18
116	58.5	47.5	100	97.7	"	100	98.3	98.0	100	"	"	99.14
110	59.0	73.0	"	100	"	"	97.9	98.7	99.0	"	"	99.10
116	48.0	60.0	"	98.1	"	"	97.9	99.0	100	"	"	98.92
115	45.0	45.0	"	100	"	"	99.7	97.2	97.2	"	98.0	98.69
110	62.5	69.5	"	"	"	98.2	99.0	98.2	97.8	"	99.5	98.62
108	50.0	33.0	"	"	"	100	95.9	98.3	98.0	"	97.7	98.31
"	53.0	37.0	"	"	"	98.9	98.0	96.8	100	"	96.7	98.13
109	50.0	74.0	"	"	"	100	96.5	96.5	99.3	"	98.0	98.10
107	46.5	82.5	"	98.0	98.8	97.5	98.1	97.8	100	"	99.1	97.90
115	43.5	53.0	"	100	100	90.3	97.5	95.5	91.5	99.0	97.8	96.92
107	47.5	83.0	"	90.7	99.0	95.8	97.2	96.5	98.2	100	97.2	96.76
Averages				99.22	99.91	99.19	98.53	98.29	98.66	99.64	99.10	

The relative difficulty of killing the various stages of the insect is shown in Figure 122.

SUMMARY.—Field experiments have shown that kills of 99% or better can be obtained with 100% dosages of hydrocyanic acid in all areas where the red scale is classed as resistant.

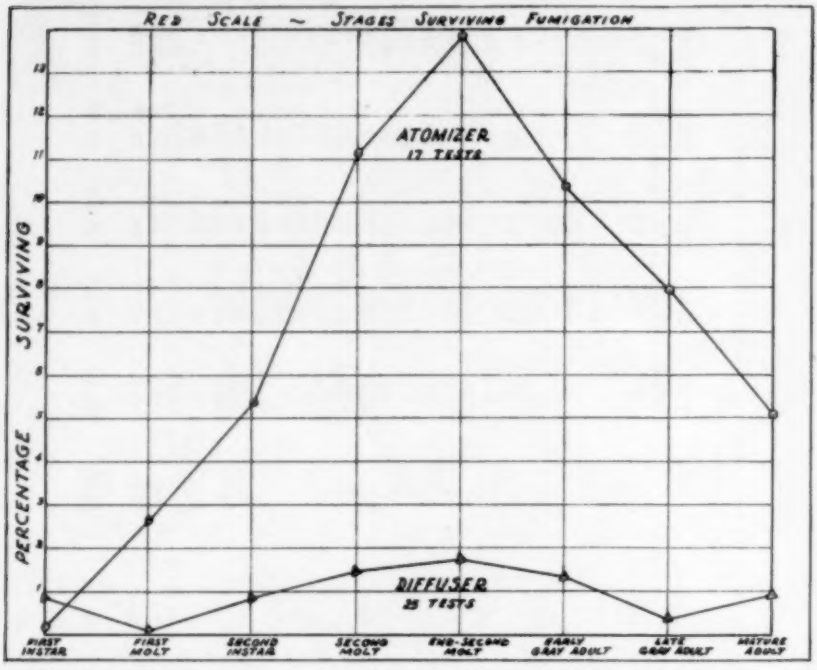

FIG. 122.—The percentage of survivors in different stages of development.

The difficulty in killing red scale by hydrocyanic acid fumigation in certain areas in California cannot be due to an acquired tolerance to hydrocyanic acid since good kills and very poor kills may be obtained in the same orchard even on the same night.

A series of fumigations during the summer season indicate that when the hydrocyanic acid is applied by atomization, the kill diminishes as the temperature increases.

In winter fumigations this relationship between kill and temperature is masked by other factors.

Winter fumigations, in which the hydrocyanic acid is applied with the atomizer, show poorer kills when the relative humidity is below 50%.

Winter fumigations, in which the hydrocyanic acid is applied with the Diffuser, show the kills independent of relative humidity.

Poor kills obtained during the winter where the hydrocyanic acid is applied with the atomizer are due to low soil temperatures causing faulty distribution of the gas in the tent.

The average kill of a series of fumigations with the Diffuser is higher than the average kill obtained with the atomizer and is more uniform.

The red scale is most difficult to kill at the end of the second molt.

In fumigations where results are poor, survivors occur in all stages of development not merely in the second molt.

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FIELD TESTS OF THE EFFICACY OF COLORED LIGHT IN TRAPPING INSECT PESTS

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With the increasing vigor with which food and drug administrations and health authorities are enforcing government regulations pertaining to dangerous chemical residue on fruits and vegetables, entomologists must give more attention to the control of insects and related pests by means other than chemicals toxic to human beings. In practically every instance civilized man will need to modify his mode of living, his agricultural practice, animal husbandry, et cetera, to meet effectively his closest competitors, the insects and their kin.

The entomologist is usually called upon for quick action and his first thought is a toxic chemical spray or dust just as the first thought of the soldier is his rifle and machine gun. In both cases the first waves of the invading enemy are usually checked, but as the persistent hordes of invaders continue to advance, other means of control must be put to use,—these are usually supplemental but may actually become of primary importance. These supplemental, though potentially primary, methods of control are usually the result of long years of research including an intensive study of the enemy's habits and ways of living.

We wish today to emphasize only one of these supplemental, though potentially powerful weapons in the battle against our insect enemies, namely, light and particularly colored light.

In spite of the often tremendous biotic potential displayed by most of our dangerous insect pests, these organisms are dependent upon their physical environment for their very existence. The power which these forces of nature, such as light, moisture, evaporation, and so forth, exert upon these insect hordes, may be made a matter of great consequence in control operations. Our thought is to harness these forces and turn this influence against the enemy for purposes of destruction.

REACTION TO THE INTENSITY OF LIGHT.—Light exerts a powerful influence over probably all insect life. We have hardly begun to realize the power of this influence. The parts played by intensity and color are fascinating fields for investigation. For some species it is likely that intensity may play a more important rôle than color.

THE CLEAR LAKE GNAT.—During the summer months the Clear Lake Gnat, *Chaoborus lacustris*, appears in great swarms about lights in the neighborhood of Lakeport, Lake County, and constitutes a real nuisance. In 1927,[1] a study of the life history of this insect was undertaken and control experiments with light were conducted. A plain white 300-watt Mazda lamp suspended over a suction-fan was used to draw the myriads of chaoborid gnats into a bag. (Fig. 123). On two occasions one trap collected eleven pounds of gnats in two hours (156 pounds during the summer). This investigation was revived during the summer of 1933. We were principally concerned with color preferences and influence of intensity.

Various colored lights (all gas discharge tubes) such as ultra-violet, blue violet, dark blue, light blue, green, two different intensities of red, and eight different intensities of white incandescent lamps were set up along the shore of Clear Lake, near Rainbow Camp (Fig. 124). These various combinations were run at different times using various types of devices and when possible were compared with a constant as a check against the variations in population due to other ecological differences, such as the season of the year, temperature changes, wind currents, etc. The data presented at this time is incomplete and should be considered only as an indication of this insect's reaction to light.

When various colored lights of equal intensity (60 watt) were set up, approximately the same number of gnats was collected over a given period of time from each trap, irrespective of the color. That is to say, the

[1]Herms, W. B., and R. W. Burgess, 1928. Combined light and suction-fan trap for insects. Electrical West, Vol. 60, No. 4, pp. 204–205.

gnats responded about equally in number to wave lengths of light of equal intensity ranging from 3500 A° to 7000 A° without any apparent peak of response.

The next step we undertook was to determine whether a change of intensity would affect the number of gnats attracted to the lights. If so, was this change proportional to the difference in intensity? Two lights of the same color, namely light blue (both discharge tubes) which had an intensity ratio of 30 to 8 were set up. During a two hour period (8:52 P. M.–10:55 P. M. on July 27, 1933) the brighter (30 ma) light at-

FIG. 123.—(a) Showing original light trap with suction fan used to catch Clear Lake gnats. (b) Pile of gnats showing a two hour catch of eleven pounds. A 12 inch ruler is shown in the heap.

tracted 18.0 gnats per second as against 5.0 gnats per second to the weaker (8 ma) light. When interchanged with two red lights (both discharge tubes) having the same ratio of intensity as the blue, namely 30 to 8, approximately three times the number of gnats was attracted to the more intense light.

Three lights, 40-, 150-, and 300-watt incandescent lamps all in the same type of device were set up. During a 20 minute period (8:15 P. M.–8:35 P. M. on July 27, 1933), the 40-, 150-, and 300-watt light devices collected 434, 1065, and 1590 gnats per second, respectively. This experiment indicates that as the lights increased in intensity from 40-watts to 300-watts there was a proportional increase in the number of gnats attracted to the lights.

Various combinations of higher intensity lamps (500-, 1000-, and 1500-watt) were also set up in different devices at a different time. The 500-watt device attracted 1480 gnats per second (during a 20 minute period, 8:10 P. M.–8:30 P. M. on July 27, 1933) and the 1500-watt device attracted 1175 gnats per second (during a 10 minute period, 8:20 P. M.–8:30 P. M. on Sept. 13, 1933) the latter being approximately the same number as would be attracted to a 200-watt white Mazda lamp. There is evidence of a decrease in the number of gnats coming in to the lights of higher intensity but just where the point of deterrence occurred was not definitely established.

The results of these various tests indicate that the gnats probably have no selective color response and that the rate of attraction is due to a function of intensity and not to a function of difference in wave length of the light.

Influence of High Intensity on Worminess (Codling Moth) in Apples.—Insects that are attracted to *low* intensities of light or are at least not light bound under low intensities, such as the codling moth, might theoretically be kept out of a given habitat by the use of *high* intensities of light. On this theory we conducted some tests in an apple orchard in Sonoma County[2] during the summer of 1929. A summary of these tests covering an entire season of nightly illumination follows, white light of high intensity being used for its repellent effect:

1. The total number of apples (from 51 trees) examined for worminess was 217,975 including thinnings and windfalls. Worminess in apples among varieties that were represented in each group, namely Yellow Newtown, Skinner Pippin, Hoover, and Ben Davis, from the unsprayed, wholly illuminated trees (eight) was 49.7 per cent, while the unsprayed check plot (not artificially illuminated) of eight trees showed 71.3 per cent worminess (Table 1). In spite of the fact that a higher artificial light intensity had been used during the second season's work, the relative reduction in worminess for the entire test plot under illuminated and nonilluminated conditions was not greatly changed; i. e., the first season it showed a reduction of 31 per cent (illuminated 14.5 per cent and nonilluminated 21.0 per cent) while the second season showed a reduction of 30 per cent (illuminated 49.7 per cent and nonilluminated 71.3 per cent).

2. Using a single variety, namely Skinner Pippin, the conclusion is reached on the evidence at hand and under the conditions of this test that the percentage of worminess of apples in the more highly illumi-

[2]Herms, W. B. 1932. Deterrent effect of artificial light on the codling moth. Hilgardia, Vol. 7, No. 7, pp. 263–280.

nated area is much less than the average for the several varieties combined; i. e., there is an apparent reduction of more than 50 per cent (illuminated 44.1 per cent; non-illuminated 89.1 per cent).

COLOR REPELLENCY.—Repellency as already intimated may also be achieved by the use of certain colors; e. g., certain species of flies are repelled by amber colored light. Swimming pools, pleasure resorts, and athletic fields that are used at night are usually invaded by numerous annoying insects attracted to light. What lights to use to repel certain insects and at the same time afford sufficient illumination is no small problem. In general, little progress has been made in this field. A laboratory set up of no small proportions is necessary to determine the reactions of insects to colored light, whether related to repellency or to attraction. Even though a high degree of purity in color may be achieved in the laboratory, and that is not an easy matter, the practical use of colored light for field control may offer almost insurmountable difficulties, particularly in the cost of illuminating elements. Although electrocuting devices are generally used to kill insects attracted to light, we should continue to search for an attracting light that itself has lethal effect. As it is now, the light whether white or colored is only used to attract the insects, and some other way must be found to destroy them before they escape, such as the suction fan already mentioned used to draw chaoborid gnats into a bag at Clear Lake, and also electrocuting devices.

COLOR ATTRACTION.—We have found in our laboratory tests, though far from complete, that insects have a high degree of color selection. Since the colors of the visible spectrum are to be found in white light it will be seen that all positively phototropic insects, whether good, bad, or indifferent, will be more or less attracted to white light. If the various species of insects have their own particular color to which they respond, it is reasonable to believe that a high degree of selectivity will be achieved through the use of monochromatic light. Thus a color particularly attractive to the codling moth would have a high degree of selectivity for that species. In our laboratory tests extending over a long period of time, using Wratten filters and other color screens as well as gas discharge tubes, we believe we have come pretty close to the color preference of the codling moth; namely, light blue. To test this color in the field, specially constructed tubes were used, always bearing in mind our practical limitations in that even the most monochromatic light that we could secure showed, on spectral analysis, several lines of different wave lengths. The higher degree of purity the greater will be the selectivity of the light and consequently the surer will be the results.

FIG. 124.—Showing experimental insect electrocuting trap as used at Clear Lake for chaoborid gnats.

FIG. 125. — Showing experimental trap set up in an apple orchard for codling moth tests.

EFFECT OF COLOR ON WORMINESS (CODLING MOTH) IN APPLES.—To compare the effectiveness of colored light (Fig. 125) traps were placed in an apple orchard in Sonoma County, through the courtesy of Mr. Alfred Hallberg, during the summer 1933. Red, blue, and white lights were used. The period of illumination extended from May 12th to October 16th, with the lights on from 5 P. M. to 5 A. M. Thirty-six trees were used in this experiment and 19,220 apples (a fair sampling) including windfalls and picked fruit were examined for worminess (Table 1). Worminess in apples among varieties that were represented in each group; namely, Yellow Newtown, Skinner Pippin, Hoover, Baldwin and Ben Davis, from trees influenced by the blue light and not sprayed showed 50.3 per cent worminess (the same group with intense white light in 1929 showed 49.7 per cent), while those in a check plot not artificially illuminated and not sprayed showed 73.6 per cent worminess (71.3 per cent in 1929). Apples under the blue, and sprayed, showed 34.5 per cent worminess, and those not illuminated and sprayed showed 40.1 per cent worminess. This indicates a very defective spray program, since our 1929 spray plots showed only 7.4 per cent worminess. Apples under the

TABLE 1. SHOWING PERCENTAGE OF WORMINESS IN APPLES UNDER CONDITIONS OF ILLUMINATION (COLORS AS INDICATED). THIS TABLE ONLY SHOWS A FAIR SAMPLE OF COMPLETE DATA

Tree No.	Variety	Illumination	Apples examined	Per cent wormy	1933 total per cent wormy	1929 total per cent wormy
*15	Ben Davis		492	55.5		
*16	Hoover	None	253	32.8	40.1	7.4
*17	Yellow Newtown		450	34.6		
*18	Skinner Pippin		551	34.3		
*12	Hoover	Blue	647	27.3	34.5	—
*13	Baldwin		554	42.9		
1	Ben Davis		411	67.9		
2	Hoover		100	26.0		
3	Yellow Newtown		241	43.5		
5	Ben Davis	Blue	573	58.1	50.3	49.7
6	Skinner Pippin		663	38.3		(white)
7	Ben Davis		502	64.9		
9	Skinner Pippin		631	46.4		
10	Skinner Pippin		491	40.9		
4	Ben Davis		441	83.4		
8	Baldwin	Check†	533	65.8	73.6	71.3
11	Baldwin		876	72.1		
14	Hoover		255	73.3		
32	Baldwin	Red	251	77.3	77.3	—
30	Yellow Newtown		539	70.6		
33	Ben Davis	White	400	68.7	74.2	—
34	Baldwin		654	80.6		
	Total		19,220			

*Trees receiving usual spray treatment.
†Check plot neither sprayed nor illuminated.

red not sprayed showed 77.3 per cent worminess, and white light non-sprayed gave 74.2 per cent worminess; i. e., slightly wormier than apples neither illuminated nor sprayed.

TABLE 2. SHOWING SEX RATIO OF CODLING MOTHS TRAPPED IN ORCHARD TEST OVER PERIOD OF EXPERIMENTAL ILLUMINATION AS INDICATED

Color of the lights	Number of days illuminated	Total number of moths trapped	Females Number	Females %	Males Number	Males %	Ratio ♀ ♂
2-Blues (Plot 1)	88	1,105	502	45.5	603	54.5	4:5
2-Blues (Plot 2)	101	1,825	797	43.7	1,028	56.3	4:5
White (60-watt)	101	132	34	25.8	98	74.2	1:3
Red (60-watt)	41	271	91	33.5	180	66.5	1:2

Although the evidence points toward a considerable reduction in worminess under the blue; i. e., a worminess of 50.3 per cent against 73.6 per cent non-sprayed and non-illuminated, and 77.3 per cent under the

red and 74.2 per cent under the white (both non-sprayed), we do not recommend the use of the codling moth-blue (Monolite) traps as a substitute for sprays. Table 2 shows sex ratio of codling moths based on moths captured in experimental traps as indicated. Many of the moths were lost due to weather conditions hence the number actually collected for study of sex ratio is much smaller than the number actually electrocuted. The losses were pretty well distributed so that the counts noted in the table represent a fair sampling.

Dried Fruit Insects.—In our laboratory experiments we found that *Ephestia figulilella* showed a color preference slightly different from that of the codling moth. It hardly seemed possible that so slight a difference in color could make so much difference in attractiveness. Tests made in fig drying yards at Fresno showed the effect of this difference.

The results of four nights' trapping in a fig drying yard at Fresno with two light traps October 11–15, 1933, showed that the darker blue light captured a total of 1578 adult *Ephestia figulilella* while the lighter blue trapped 739, somewhat less than half as many. The percentage of females captured was about the same in both traps; namely 51.9 in the dark blue, and 53.4 in the light blue. In commenting on this test, Mr. Perez Simmons, Entomologist in Charge, states, "We feel that further tests of the dark blue light are desirable against dried fruit insects." Also that, "Moths were quite numerous in this yard and the results of the trapping seem quite satisfactory to Mr. Donohoe, who thinks the traps materially reduced the population of moths."

During the past year extensive tests have been made in dried fruit warehouses in San Jose, Hollister, Colusa, Napa, Santa Clara and Berkeley with excellent results. In one warehouse one trap averaged 1000 moths (*Ephestia* and *Plodia*) per night for a number of nights with the result that the warehouse was well cleared of these pests.

Artichoke Plume Moths.—An experiment for the control of the artichoke plume moth, *Platyptilia carduidactyla*, was conducted near Half Moon Bay on the Manuel Roach ranch during the period December 20, 1933 to April 1, 1934 (Fig. 4). Three plots of artichokes were used: plot No. 1, four acres, with four midnight blue lights (all 60-watt mercury discharge tubes of dark blue glass); plot No. 2, three acres with three 60-watt lights, a red (neon discharge tube of clear glass), a midnight blue (mercury discharge tube of dark blue glass), and a white incandescent lamp; and plot No. 3, five acres used as a check.

Although the artichokes had been growing since August 1933, the first record of worminess of picked artichokes in the three fields was made on January 10, 1934, showing approximately 20 per cent worminess

FIG. 126.—Showing artichoke field with experimental traps set up for plume moth tests.

(Table 3). The field illuminated by the four midnight blue lights steadily decreased in worminess over the period until at the end of the season, the artichokes picked were only 1.8 per cent wormy, while the check plot increased in worminess to 29.4 per cent, decreasing again to 20 per cent at the end of the season.

TABLE 3. SHOWING PERCENTAGE OF WORMINESS IN ARTICHOKES UNDER ILLUMINATED CONDITIONS

Date 1934	Plot No. 1 4 blue lights		Plot No. 2 Red, white, blue		Plot No. 3 Check	
	Total boxes	Per cent wormy	Total boxes	Per cent wormy	Total boxes	Per cent wormy
Jan. 10	6.5	23.0	2.5	20.0	—	—
Jan. 15	—	—	—	—	10.0	20.0
Feb. 5	—	—	—	—	17.0	29.4
Feb. 7	11.5	13.1	7.0	28.4	—	—
Feb. 12	—	—	—	—	17.5	22.9
Feb. 14	17.0	8.8	7.5	40.0	—	—
Mar. 5	—	—	—	—	16.0	25.0
Mar. 7	15.5	3.2	19.5	18.0	—	—
Mar. 12	—	—	—	—	14.75	18.6
Mar. 14	13.25	1.9	17.0	17.6	—	—
Mar. 16	—	—	—	—	18.75	20.0
Mar. 21	8.0	1.8	16.75	10.4	—	—

Due to storms and resultant accidents to the traps many of our moth catches were destroyed or water soaked so that an accurate count could not be made. The following numbers (Table 4) are rather too small to be

significant, though interesting. During this period 649 artichoke plume moths were taken (with above limitations) by the four traps (containing midnight blue tubes) in plot No. 1, of which only 99 could be identified as to sex, 60 females and 39 males, a ratio of 3:2. The blue light trap in plot No. 2 gave 43 plume moths of which 16 were females and 10 were males, again a ratio of 3:2. The white light trap electrocuted 39 plume moths, of which one was a female and eight were males, a ratio of 1:8. The red light burned for a comparatively short time, and but one plume moth was taken.

TABLE 4. SEX RATIO OF ARTICHOKE PLUME MOTHS TAKEN IN LIGHT TRAPS

Color of the lights	Number of days illuminated	Total number of moths trapped	Females	Males	Ratio ♀ ♂
4-Blues	78	649	60	39	3:2
Blue	46	43	16	10	3:2
White	39	16	1	8	1:8
Red	21	1	—	—	—

While the test with colored light indicates a satisfactory reduction in worminess due to the plume moth, it must be repeated on a larger scale and for a longer period of time before the use of light in the control of the artichoke plume moth can be recommended. We plan to start a second season's test in September.

GRAPE LEAFHOPPER.—An experiment for the control of the grape leafhopper, *Erythroneura comes* is now in progress in vineyards in northern Kern County. Since the test has been in progress only about two and a half months at this writing (June 1) the results here reported may only be taken as a report of progress.

Three vineyards of eight acres each are under experiment (Fig. 127). Plot No. 1 contains four traps with midnight blue lights (all 60-watt mercury discharge tubes of dark blue glass). Plot No. 2 contains three traps: a red light (60-watt neon discharge tube of clear glass), a midnight blue light, and a white 60-watt incandescent lamp. Plot No. 3 is used as a check. No other methods of control are employed in these plots.

During the period, March 18 to May 23, inclusive, the four midnight blue lights in plot No. 1 have collected a total of 192,597 grape leafhoppers, an average of 764 "hoppers" per trap per night. In plot No. 2 the midnight blue light attracted 40,539 leafhoppers, an average of 643 "hoppers" per night; the red light took a toll of 54,666 "hoppers," an average of 867 per night, while the white light of 60 watts averaged 399 per night and the 100-watt white light averaged 840 per night. Table No. 5 shows only a portion of the data for the total period; i. e. counts representing a fair sampling are shown for the months of March, April, and May.

TABLE 5. SHOWS NUMBER OF GRAPE LEAFHOPPERS CAPTURED IN LIGHT TRAPS DURING PARTS OF MARCH, APRIL, AND MAY, A FAIR SAMPLE OF COLLECTIONS MADE CONTINUOUSLY THROUGHOUT THE PERIOD OF ILLUMINATION

Date	Daily temperature Sunset		Min.	Max.	Weather	Number of grape leafhoppers Plot No. 1 Blue				Plot No. 2 White	Blue	Red
1934	P.M.	°F	°F	°F	(12 noon)	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Mar. 21	6:12	71	47	—	Breezy, clear	1,121	1,205	1,604	1,644	1,101	1,011	1,661
22	6:13	70	46	—	Breezy, cloudy							
23	6:14	61	46	—	Breezy, clear	1,322	1,121	1,455	1,696	1,009	1,012	1,790
24	6:15	70	52	—	Breezy, clear							
25	6:16	72	48	—	Breezy, clear							
26	6:18	71	44	—	Breezy, clear	1,361	1,355	1,421	1,705	906	1,210	1,960
Apr. 25	6:47	66	46	82	Windy, warmer	1,955	1,760	1,705	1,918	2,117	1,405	2,050
26	6:48	70	48	93	Windy, warmer							
27	6:49	70	47	92	Windy, cooler	2,150	1,957	1,995	2,255	2,276	1,951	2,155
28	6:50	69	47	90	Windy, cooler							
29	6:50	69	44	88	Windy, cooler							
30	6:51	60	47	76	Cloudy, sultry	1,660	1,521	1,455	1,412	1,860	1,821	1,722
May 16	7:07	70	54	88	Warm, clear	1,907	2,021	1,935	1,820	1,805	1,550	1,650
17	7:08	63	48	89	Warm, clear							
18	7:08	64	48	89	Warm, clear	1,866	1,982	1,890	1,895	1,800	1,670	1,905
19	7.09	67	48	92	Warm, clear							
20	7:10	68	50	98	Cooler, breeze							
21	7:11	70	54	104	Warmer, breeze	2,105	2,055	2,025	2,105	1,907	1,960	1,935
Total leafhoppers trapped (Mar. 18 to May 23)							192,597			47,217	40,539	54,666
Average per trap per night							764			399	643	867

Two population counts (Table 6) have been made to date. The results on May 2d showed an average of 68.7 adults per vine in plot No. 1 affected by variety of colors as shown, while in the untreated check plot (No. 3) there were 280 leafhoppers per vine. On May 16 plot No. 1 showed an average of 53.7 adults per vine, a slight decrease since May 2d. Plot No. 2 showed 40.4 adults per vine, a considerable increase since May 2d. Plot No. 3 (check plot) showed 383.2 adults per vine, also an increase since May 2d.

On March 30 a sex ratio count (Table 7) was made of the leafhoppers in the various traps. The four midnight blue lights had an average of 1760 "hoppers" per trap of which 88 per cent were females and 12 per cent males, a ratio of 7:1. The red light had 2966 "hoppers," of which 7 per cent were females and 93 per cent were males, a ratio of 1:14, while the 60-watt white light had 1012 "hoppers," of which 38 per cent were females and 62 per cent were males, a ratio of 2:3. This latter is believed to be the normal ratio in the field.

FIG. 127.—Showing experimental light trap set up in a vineyard.

This experiment is still in progress; hence no reliable prediction can be made as to the final results, in spite of the fact that the population counts and appearance of vines look promising.

TABLE 6. SHOWS GRAPE LEAFHOPPER POPULATION COUNTS (AVERAGE FOR SEVERAL STATIONS) AT AN INTERVAL OF TWO WEEKS (MAY 2, AND 16)

	Plot No. 1 4 blue lights		Plot No. 2 White blue red		Plot No. 3 Check	
Date 1934	Number of stations	Leafhoppers per vine	Number of stations	Leafhoppers per vine	Number of stations	Leafhoppers per vine
May 2..	15	68.7	9	16.7	5	280.0
May 16.	6	53.7	6	40.4	4	383.2

TABLE 7. SEX RATIO OF GRAPE LEAFHOPPERS TAKEN IN LIGHT TRAPS ON MARCH 30, 1934

Color of the lights	Total leafhoppers trapped	Females	Males	Ratio ♀ ♂
Blue (60-watt).....	1,760	88	12	7:1
Red (60-watt).....	2,966	7	93	1:14
White (60-watt).....	1,012	38	62	2:3

We trust that the experimental nature of this investigation is fully realized. Even in the case of our most promising tests, we are not recommending the use of light traps of appropriate color or intensity, except as perhaps a supplemental measure.

We have much more to do in our laboratory in the purification of the colors used for testing. It is an experiment full of interest and fascination not only in relation to night flying insects, but particularly in relation to day fliers such as the California oak moth and the cabbage butterfly, both of which have been tested in a preliminary fashion.

ACKNOWLEDGMENTS.—We are greatly indebted to the California Committee in Relation to Electricity to Agriculture (C. R. E. A.) which has given generous support to our investigation. We are also indebted to Dr. L. T. Jones of the Electrical Products Company, for his valuable assistance in the construction of our experimental traps. To the growers who have so willingly placed their plantings at our disposal, we owe a deep debt of gratitude.

NOTES ON FIELD TRAPPING OF LEPIDOPTERA ATTACKING DRIED FRUITS

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Ephestia figulilella Gregson is one of the serious pests of dried fruits in California. At the suggestion of the personnel of the Dried-Fruit-Insect Laboratory of the Bureau of Entomology at Fresno, it has been named the "raisin moth." This common name is now generally accepted among producers and packers of dried fruit in the San Joaquin Valley of California.

By the spring of 1931 investigations showed that the raisin moth exists out of doors the year around in the Fresno district. Moreover, it became increasingly evident that the larval infestations encountered in storages and in packing houses had originated on the ranches before the delivery of the fruit.

In order to secure information on this species in the field during the period of adult activity, tests of the effectiveness of a number of attractant liquid baits were conducted. Among the materials tried were water-diluted preparations of cranberry sauce; cranberry sauce and yeast; tea; tea, milk, and sugar; vinegar; a proprietary malt sirup and yeast; malt sirup, yeast, and nicotine sulphate; and a special malt sirup used in codling moth trapping with yeast. The cranberry sauce and the vinegar

mixtures were tried because the raisin moth had been observed to feed on the drip of souring figs, the acid flavor of which resembles both sour cranberries and vinegar. The other preparations had been tried with some success by other workers in trapping insects. Malt sirup has been used extensively in trapping the codling moth in apple orchards. The preliminary tests[1] were conducted from March to May 1931, in a warehouse having a large population of moths. Sauce pans 3 inches deep by 9 inches wide, filled with about 2 quarts of liquid, were used as traps. The bait was replenished at intervals of from 4 to 10 days.

A preparation of ½-pint of malt sirup, yeast, and 2 quarts of water per trap proved the most effective and was adopted for field use, with control traps of water. Through a period of 57 days' exposure in a warehouse, the malt-sirup traps averaged 12.80 moths per trap per day and the controls 7.36. Subsequent field tests indicated that the malt-sirup content could be reduced to ¼ pint per 2 quarts of water without reducing its effectiveness. This proportion was used in all trapping after August 11, 1931.

Other workers have recommended the use of 0.5 per cent of benzoate of soda to prolong the attractiveness of codling moth baits. In comparative tests of the malt-sirup preparation with and without the addition of benzoate of soda over a 10-day period the regular traps captured from 4 to 10 times as many moths as did those containing the preservative. No fermentation of the benzoate of soda baits was evident.

The efficiency of the traps diminished rapidly after the fourth day of exposure, probably because of slowing down of fermentation in the bait. After July 12, 1931, the traps were visited, the insects removed, and the liquid renewed at intervals of 3 or 4 days, the regular weekly circuit of traps being made on every Tuesday and Friday.

When removing the catches of insects the individual trap contents were stirred with a rubber-bladed plate scraper, the contents poured through a 2-inch tea strainer, and the insects emptied into wide-mouthed pint jars about half filled with water. For the segregation of the species in the laboratory, the contents of the jars were poured onto the surface of a cloth stretched tightly over a 1-foot-square wooden frame placed over a dish pan. With the cloth divided into 4-inch squares with India ink, the danger of overlooking any insects was much reduced. This point is important, since several thousand Diptera and other miscellaneous insects, frequently taken in a single trap, increase the difficulty of separating the species to be recorded. Covers over the traps, made of ¼-

[1]Austin W. Morrill, Jr., and Perez Simmons took part in this work.

inch wire screen, were found to be effective in excluding butterflies and large moths, and in preventing depredations on the catches by mockingbirds.

The species of moths on which data were desired can best be separated by a microscopic examination of the external genital characters of the males and dissection of the females and examination of the markings on the bursa copulatrix of each. For the binocular examination, a counting dish was devised which consists of a Petri dish cover divided by paraffin partitions into four equal segments. All binocular examinations were made with the insects submerged in 70 per cent alcohol. During 1931 a portion only of some of the larger catches was examined and the numbers of the various species estimated from the proportions of each in the samples. In 1932 and 1933, however, all dried-fruit Lepidoptera taken were actually determined. During the 1933 season it became possible to recognize most specimens of the raisin moth at sight, greatly reducing the amount of microscopic work.

TRAPPING DATA.—Traps were operated in 1931, 1932, and 1933 in a variety of locations in orchards and vineyards. Two control traps containing water were operated throughout the 1931 season in a vineyard of Muscat grapes. From May 28 to November 12, inclusive, these control traps captured an average of 30.5 moths each as compared with an average of 3,007 each in the malt-sirup baits.

Recently-discovered information concerning the overwintering of larvae and emergence of the spring brood of adults leaves the accuracy of previous interpretations of graphic representations open to question. For the present it is sufficient to say that at least three generations of the raisin moth normally occur annually in the San Joaquin Valley.

The most surprising result of the trapping was the capture throughout each season of several species of moths of cosmopolitan distribution noted for their attacks on stored food products. The fact that they were taken at widely divergent points under typical field conditions and over a period of 3 years indicates that they all occur as endemic field species in the Fresno district.

The areas trapped included one Muscat, two Thompson Seedless (Sultanina), and one Zante ("currant") vineyard; one Mission, one Calimyrna (California-Smyrna), and one Adriatic fig orchard; an apricot orchard; and beneath a mulberry tree. In 1931, five traps were operated in each location and in 1932 and 1933 three traps each, with the exception of that under the mulberry tree, where one trap only was used. Catches of the predominant species, the raisin moth, ranged from 0 in early April and late November to a maximum of 122.2 per trap per day

over a 3-day period, September 22–25, 1931, in a Mission fig orchard.

The peak of seasonal abundance of adults was reached each year in late September and early October. Each season the Mission fig orchard yielded more moths per trap than any of the other locations during the same period. Catches in the Thompson Seedless vineyard, the apricot orchard, and beneath the mulberry tree were small. The last two were trapped only during the period of ripening of the fruit, and at this time the ripe fruit appeared more attractive to the moths than did the fermenting bait. A total of 7,181 days catches were recorded.

In Table 1 are shown the total catches of all species recorded during the three seasons. The percentage of females is based on the examination of 35,556 specimens of the raisin moth and for the other species it represents the examination of all the individuals taken in 1932 and 1933. The totals for *Ephestiodes nigrella* Hulst, *Pyralis farinalis* L., and *Vitula serratilineella* Rag. are doubtless incomplete, since the first two were imperfectly recognized in 1931 and the last not at all until 1933.

TABLE 1. TOTAL CATCHES OF THE RECORDED SPECIES OF MOTHS TAKEN IN BAIT TRAPS AT FRESNO, CALIF., 1931–1933

Species	Total catch	Percentage of total	Percentage of females
Ephestia figulilella Greg	53,480	96.80	44.5
Ephestia elutella Hbn	248	0.45	68.1
Ephestia kuehniella Zell	178	0.32	42.9
Ephestiodes nigrella Hulst	447	0.81	80.1
Plodia interpunctella Hbn	433	0.78	55.6
Pyralis farinalis L	457	0.83	33.9
Vitula serratilineella Rag	6	0.01	—
All species	55,249	100.00	

DISCUSSION BY SPECIES

Ephestia figulilella Greg. In 1931, 2,588 raisin moth females were examined to determine the condition of the ovarian follicles at the time of capture. Of this number, 1,660, or 64.1 per cent, were gravid. A female was considered gravid if the ovarioles near their opening into the oviduct were full of eggs as contrasted with the spent condition in which eggs were scattered and few in number.

The percentage of females captured varied considerably at different periods in each location, but the percentage indicated in the table probably represents the species very accurately since it is from more than 35,000 specimens collected over three seasons from a variety of locations and from near the beginning of field activity in April and May to its practical cessation in November.

Ephestia elutella Hbn. While the recorded catches of the chocolate moth or tobacco moth are small, they are none the less significant since they establish the presence of this cosmopolitan species in the field. Adults are frequently encountered in raisin storages in the early spring. While its occurrence in epidemic numbers in the San Joaquin Valley is not recorded, it must be regarded as a potential pest since it is definitely established in this environment. We have reared the species from dried loganberries collected in the Northwest.

Ephestia kuehniella Zell. The Mediterranean flour moth occurs both in the open and about storages. Larvae have been raised in the laboratory on raisins from parent stock from flour. We have taken no larvae from drying or dried fruits in the field.

Ephestiodes nigrella Hulst. *Ephestiodes nigrella* is a little-known species, about the biology of which nothing has been recorded. H. H. Keifer has recognized cast larval skins in raisins, and we have reared the insect in the laboratory on a mixture of walnut meats and raisins. It occurs in moderate abundance about certain raisin storage plants in the Fresno district in the spring. Adults have been reared from larvae found hibernating beneath the loose bark of grapevines in a Zante vineyard. All of the evidence at hand shows that it should be regarded as a new, though at present unimportant, pest of dried fruits.

Plodia interpunctella Hbn. The Indian-meal moth is encountered in raisin and fig storages. It preferably attacks raisins and other dried fruits that have been stored a year or more, and occasionally becomes very abundant. Larvae have been found in the field attacking figs on the ground. Although most injurious in storage houses, its occurrence outside doubtless helps to replenish storage infestations.

Pyralis farinalis L. The meal snout moth is not known to attack dried fruits although adults are occasionally encountered in the spring in raisin storages. Nothing is known about its field habits.

Vitula serratilineella Rag. The dried fruit moth is a minor pest of stored prunes in the San Jose and Fresno districts. Nothing is known about its biology in the field.

PARASITES OF THE RAISIN MOTH.—Three parasites of the raisin moth have been taken in the baits; the cosmopolitan braconid, *Microbracon hebetor* Say, the equally widely distributed *Nemeritis canescens* Grav., and the little-known *Mesostenus gracilis* Cress.; the last two are ichneumonids. The attacks by each of these species on the raisin moth constitute new host records. *M. hebetor* and *N. canescens*, at least, likewise parasitize *Plodia interpunctella*.

In the field trapping, 1,924 of *Microbracon hebetor* and 2,413 specimens of a mixed lot of *N. canescens* and *Mesostenus gracilis* were captured. During the last two seasons, when the latter two species were differentiated, 387 *N. canescens* and 149 *M. gracilis* were recorded. Catches of all three species were higher in 1931 and lower in 1933 than in 1932, representing at least temporarily a decline in abundance. All three species occur in dried-fruit storages, where *M. hebetor* especially takes a heavy annual toll of the full-grown larvae of the raisin moth.

SUMMARY.—A mixture of ¼-pint of malt sirup and 2 quarts of water plus yeast renewed twice weekly has proven of value as a trap material for experimental trapping of the raisin moth, *Ephestia figulilella*, and other stored-products Lepidoptera and their parasites in vineyards and orchards. Three seasons' operation of such traps in a variety of locations has shown the presence in the field of several species usually thought of as storage pests only. In addition to the raisin moth, these included the chocolate moth, *E. elutella;* the Mediterranean flour moth, *E. kuehniella;* the Indian-meal moth, *Plodia interpunctella;* the meal snout moth, *Pyralis farinalis;* and the dried fruit moth, *Vitula serratilineella*. *Ephestiodes nigrella*, a minor pest of dried fruits, was taken in limited numbers. Parasites of *Ephestia* and *Plodia* taken in the baits included *Microbracon hebetor*, *Nemeritis canescens*, and *Mesostenus gracilis*.

EXPERIMENTS IN THE EXCLUSION OF *EPHESTIA FIGULILELLA* GREGSON FROM DRYING FRUIT

By HEBER C. DONOHOE, DWIGHT F. BARNES, CHARLES K. FISHER, and PEREZ SIMMONS, *Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture*

Evidence at hand indicates that much of the infestation by the raisin moth, *Ephestia figulilella* Gregson, in dried fruits originates on ranches where the fruit is produced. With the exception of figs which are allowed to drop and lie on the ground for several days prior to picking up for drying, this infestation occurs almost entirely during the period of drying and while the dried product is held in temporary stacks of boxes prior to delivery to the packing houses. Raisin moth infestation seldom occurs while the fruit is on the trees.

In 1932 the writers began a series of experiments with a loosely woven fabric known as tobacco shade cloth as a means for excluding raisin moths from drying fruits and fruits held in temporary ranch storage.

Preliminary tests have been sufficiently encouraging to merit a brief discussion of the methods and results.

For the protection of fruit on spread trays, stakes 18 inches high were set in the ground at the corners and, where needed, along the sides of the area to be covered. A strand of wire fastened along the tops of the stakes formed a frame over which the cloth was stretched, the overlapping edges all around being weighted down with soil, or with odd pieces of waste lumber. After the trays were stacked and while the fruit was boxed, each stack of trays or boxes was covered with a piece of cloth secured about the bottom by soil or lumber. In no case was the cloth in contact with the fruit.

EXPERIMENTS WITH FIGS.—During the 1932 drying season the entire crop of figs from 50 Adriatic trees was harvested in 13 pickings over the period from August 15 to September 26. At each picking one half of the crop from all trees was dried spread under shade-cloth shelters and the other half was dried exposed in the customary manner. Within 48 hours after picking, samples of 50 figs each from all pickings were examined. The average infestation of orchard origin indicated by these samples was 4.7 per cent. The fruit was again sampled after it had dried, and 50-fig samples from each lot (50 samples covered, 51 exposed) were held in the laboratory for about 3 weeks before examination. Holding the samples for this period permitted the insects present to develop to such a size that they could be recognized at examination.

Seven pickings were made during the period from August 15 to September 5. During this time the maximum temperature during each drying interval exceeded 95° F. The average infestation in samples taken after the figs had been dried amounted to 2.3 per cent in the exposed trays and 0.6 per cent in the covered trays. Evidently the surface temperature of the fruit during each drying was sufficiently high partially to destroy the original infestation.

Six pickings from September 8 to September 26 were dried at daily maximum air temperatures which exceeded 94° F. only once, affecting the drying of only one lot of fruit. The average infestation in these six pickings amounted to 3.1 per cent in the figs protected by shade cloth and 38.2 per cent in those dried exposed.

In 1933 similar tests with figs were conducted on the fruit from two Adriatic, one Calimyrna, and one Mission orchard. In none of these tests was infestation by the raisin moth especially severe. The average infestation in each set was about one half as great in the covered lots as in those exposed.

EXPERIMENTS WITH APRICOTS, NECTARINES, AND PEACHES.—During the season of 1933 a portion of the crop from each drying of apricots, nectarines, and peaches in a commercial drying yard was used to test the effectiveness of shade-cloth protection while the trays of fruit were spread in the sun, during completion of drying in stacked trays, and while the fruit was being held in boxes prior to the delivery of the crop. All samples of fruit were held in the laboratory a minimum of 18 days prior to examination for infestation. Any fruit showing living or dead larvae or excrement was considered infested.

The summarized data for five dryings of apricots from samples taken at time of delivery to the packing house showed an average infestation of 0.0 per cent in fruit continuously protected, 0.0 per cent in fruit protected from the time of stacking, 5.7 per cent in fruit protected in boxes only, and 57.4 per cent in fruit handled in the usual manner with no protection.

Similar data from the treatment of four dryings of nectarines yielded 7.7 per cent infestation in fruit continuously protected, 11.0 per cent in that protected from the time of stacking, 80.7 per cent in samples protected in boxes only, and 100.0 per cent infestation in samples afforded no protection.

In the case of peaches, the average infestation in fruit continuously covered amounted to 2.0 per cent, covered from stacking 3.5 per cent, covered in boxes only 71.2 per cent, and with no protection 97.1 per cent.

An unexpected feature of the foregoing results is the indication that cloth protection of cut fruits while they are being dried on spread trays may be of little or no advantage. The infestations shown by fruits continuously covered from the time spread and by those covered from the time the trays were stacked are both 0 for apricots. The averages for those continuously covered were less than for those covered at stacking by only 3.3 per cent with nectarines and by 1.5 per cent with peaches.

EXPERIMENTS WITH RAISINS.—Three tests of the effectiveness of covering stacks of drying raisins were conducted during the fall of 1933. All samples were held at least 3 weeks before they were examined. In Test 1, with Thompson Seedless grapes in a drying yard, the fruit was infested at time of stacking to the extent of 1,408 larvae per ton. At boxing, 3 days later, the fruit that had had shade-cloth protection showed 2,141 larvae and that not protected 38,400 larvae per ton.

In Test 2, Sultana grapes dried in a vineyard were infested to the extent of 2,938 larvae per ton at stacking. In samples from the stacks after 15 days' exposure the covered fruit yielded 8,256 and the exposed raisins 56,768 larvae per ton.

Test 3 was with Thompson Seedless grapes in the vineyard. Infestation at stacking averaged 4,893 larvae per ton. The fruit was boxed after 4 days of stack drying. At this time the covered fruit averaged 7,702 and the exposed fruit 18,675 larvae per ton.

SUMMARY.—The use of tobacco shade cloth on the ranches after the picking of the crop offers promise as a method excluding infestation by the raisin moth in drying and dried fruits. Progressive sampling showed that comparatively little of the infestation in unprotected fruit takes place during the initial drying in the spread trays. Preliminary tests in the protection of figs, apricots, nectarines, peaches, and raisins have been uniformly successful.

NOTES ON HOST MATERIALS OF *EPHESTIA FIGULILELLA* GREGSON

By HEBER C. DONOHOE and DWIGHT F. BARNES, *Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture*

The raisin moth, *Ephestia figulilella* Gregson, is most common in dried fruits in California during the late fall, winter, and spring following the summer and fall in which the fruit is produced. With the establishment in 1931 of the fact that this species exists in the field throughout the year and infests fruits chiefly during the drying and curing processes on the ranches, a careful search was made for the possible field hosts involved in the insect's bionomics.

The raisin moth has been known to attack fresh grapes, raisins, figs, peaches, apricots, nectarines, prunes, and dates in California. It has been recorded as feeding on decorticated cottonseed cake from Galveston, Tex., and rice-fodder meal in Germany. In the laboratory full-grown larvae have been obtained from a closed paper bag containing a quantity of insects including *E. figulilella* killed by a light trap several weeks earlier. Since *Ephestia* have been observed to eject eggs following electrocution by this trap, it is evident that the larvae mentioned developed by feeding on dead animal matter. In the laboratory larvae feed readily on walnut meats.

FIELD OBSERVATIONS ON HOST MATERIALS.—The infestations recorded in the following discussion are all from fruits gathered prior to harvest or from waste fruits lying on the ground unharvested. Unless otherwise noted, all records are from the San Joaquin Valley. All ground samples were taken from shaded areas, as during the summer months, at least, infestation in fallen fruits exposed to the sun's rays is practically

nil. The figures per ton, where given, represent the maxima obtained to date. They are based on estimates obtained from the examination of weighed random samples.

Mulberries fall to the ground in April, May, and June during the period of pupation and emergence of the spring brood of the raisin moth. Fallen fruit has been found infested at the rate of 2,524,400 larvae and pupae per ton and 692,700 per tree. The abundance of mulberry trees in the San Joaquin Valley, combined with the fact that this is the only known host during a large part of the spring emergence period, indicates that this fruit plays a major role in the development of the high populations which attack commercial fruits during July and August.

All varieties of plums examined have shown infestation in the waste fruits. Prunes on the ground have been found infested at the rate of 23 per cent. Samples of Myrobalan and Red Beauty plums have indicated 576,000 larvae per ton and an unknown variety over 990,000 larvae per ton.

Grapes were first found infested on the vine by members of the California State Department of Agriculture. In a survey in 1932 they found 16 varieties infested. The writers have found infestations in Zante grapes ("currants") of the Red Corinthe variety, which appear to be an especially attractive food, ranging from 0 to 192,000 per dried ton in samples that had been picked from the vines. In practically every vineyard part of the grape crop is left unpicked and falls to the ground. Heavy infestations are common in this material; in fact, it appears to be the principal source of the larvae that overwinter in vineyards.

Figs of all common varieties are infested after falling to the ground, though rarely infested on the trees. The Mission variety especially, and to a lesser extent others as well, produce a first crop of as much as one half ton of dried fruit per acre. With the low prices of recent years this crop generally has been abandoned and cultivated into the soil previous to ripening of the second crop. Prior to this cultivation in early August, such fruit has been found infested at the rate of over 1,000,000 larvae per ton while 2 months later as many as 138,000 larvae and pupae per ton have been indicated from a sample of buried figs. It appears that these soil-covered figs play an important part as a source of the infestation present in fig orchards during the harvesting of the commercial second crop.

Following the cessation of second-crop harvest operations a small portion of the same crop and, notably in Missions, a distinct third crop usually fall during late September and October. These figs are abandoned. Adriatic figs collected October 30, 1933, showed the maximum

infestation yet found in such material—97,000 per ton. In these waste fruits are bred practically all of the larvae that overwinter in fig orchards, for the most part in the soil.

Waste apricots collected in August 1933 in an orchard from which the crop had been harvested for drying were infested at the rate of over 5,000,000 larvae per ton, though not more than 1 or 2 pounds of this waste fruit per tree was present.

Nectarines and freestone and cling peaches all become infested if allowed to dry beneath the trees. As many as 398,000 larvae per ton have been obtained from white nectarines.

In December 1933 a peach pit dump was found to contain over 5,000 larvae per ton. Many of the pits had split open, the kernels within being practically consumed. Pit dumps are accumulations of the pits and cull fruits left after the preparation of peaches, apricots, and nectarines for drying.

Both fresh dates on the palms and drying fallen dates on the ground in the Coachella Valley have yielded light infestations.

In addition to the principal field hosts already mentioned, pears, cherries, and apples have been found lightly infested, but none of these fruits is of common enough occurrence to be of importance as a larval food in the San Joaquin Valley.

DISCUSSION.—From the evidence at hand a picture of the succession of field hosts for the raisin moth may be obtained. Briefly characterized, mulberries serve as the early spring host, producing a brood of moths which, combined with those emerging from hibernation in June, infest apricots, first-crop figs, and other fruits. The progeny therefrom infest grapes, second-crop figs, peaches, and nectarines and produce another brood of moths which oviposit in September and October on waste figs, grapes, and other late fruits. Part of the larvae which develop in these reach full size and enter hibernation.

SUMMARY.—A list of the field hosts of the raisin moth includes waste mulberries, plums, prunes, grapes, figs, apricots, nectarines, peaches, peach pit kernels, pears, cherries, apples, and dates. This succession of fruits provides for the entire annual cycle of the insect in the field. Its increase in these waste fruits largely explains its usual abundance during the harvesting and drying of the various commercial fruit crops.

PEST CONTROL AND THE NEW DEAL

By ROBERT K. VICKERY, *California Spray-Chemical Corporation, Berkeley, California*

During the last six months the writer has been devoting most of his time to the development of a Code of Fair Competition for the Insecticide Industry. The committees working on the Code have found it interesting to look into the future and estimate the growth of the pest control business. The present business in the United States is approximately twenty-five million dollars per year. What will it be ten, twenty-five or fifty years from now? The industry has grown from nothing in the last fifty years. Will the present rate of growth continue?

It is not much more than fifty years since modern agriculture was born. Prior to that time pest control was left to Providence and starvation was a constant menace to peoples all over the world. Since the development of modern agriculture with its use of machinery and long distance transportation the problem has not been starvation but overproduction. Ever since the war overproduction has kept agriculture in a state of chronic bankruptcy. During this period of overproduction, Economic Entomology has grown extraordinarily. Fifty years ago there were scarcely a dozen Economic Entomologists in this country. Now this Association has over twelve hundred members. Agriculture has demanded Entomologists to protect its crops from Insect pests so as to increase production. At first glance it seems strange that there should be such a demand for increased production in the face of overproduction. The answer according to Economists is simple,—The greater the production of the individual grower for a given acreage, the better are his chances of a profit. Overproduction is a problem of the particular industry as a whole.

President Roosevelt, I believe, is seriously trying to give agriculture a new deal. Agriculture like business has been taken into the experimental laboratory. Every plausible scheme to put agriculture on a profitable basis has been given a trial. Many of the experiments are doomed to fail. The world recognizes that it is necessary that agriculture must be put on a profitable basis by some method or other. Personally, I believe, that Secretary Wallace's idea of purchasing marginal and surplus lands may be the solution to the problem. If economic entomology has grown in times of depression, the growth should be even more extraordinary when agriculture is prosperous and there is money to be spent for pest control.

The Insecticide Industry is naturally concerned in knowing if the increased interest in economic entomology will result in increased con-

sumption of insecticides? Will a reduction in acreage mean a reduction in demand for insecticides or will the more intensive form of agriculture now developing require more insecticides? Will the trend in Economic Entomology be toward chemical control or toward biological control? Will the Quarantine Service be able to keep out, in the future, the insect invaders that have in the past opened new fields for pest control? Personally, I do not want to assume the role of prophet and try to answer these questions. I am certain, however, that we can expect to see remarkable developments in economic entomology in the years to come.

During the last fifteen years the cost of insecticides has constantly decreased. As these costs go down, the field for pest control expands to include more and more low profit crops. At the present time there is a rapid evolution in chemical methods of pest control. New materials are being developed and old products improved. All of these improvements either reduce the cost or increase the efficiency of pest control. For example the VAPO DUSTS described in previous papers have made it possible to profitably control the Beet Leaf Hopper and have cut one third off the cost of winter spraying of deciduous fruits with oils for Scale, etc. These more efficient and economical insecticides should increase the use of pest control methods.

This paper frankly contributes nothing in the way of original research. It has been given with the thought that the economics of economic entomology should be a subject of interest to this gathering.

A GYNANDROMORPH HONEYBEE

By J. E. ECKERT, *Assistant Professor of Apiculture, University of California, Davis, Calif.*

Gynandromorphism, the incorporation of a part of both sexes in one individual, is said to be quite common among the Lepidoptera but is comparatively rare among the Hymenoptera. In the present instance, the writer discovered a nearly bilateral gynandromorph honeybee crawling aimlessly about in front of a colony in the experimental apiary of the University of California, at Davis. In size it was the equivalent of a normal drone, being 18 mm. long and about 5.5 mm. wide between the bases of the forewings. Its head was a bit smaller than one finds in the average drone and was carried slightly to one side. The last segment of the abdomen was noticeably distended and moved in and out as if the bee was in distress. In other respects the behavior and appearance of the bee was not very noticeably abnormal.

Upon close examination a distinct line was found in the dorsal middle portion of its body, dividing the monstrosity into two portions; the right side bore female appendages while on the left side the appendages were typical of the male. The front parts of the head were slightly askew with the antennae inserted at different angles. The three ocelli were crowded on the left side of the dividing line and were situated just above the insertion of the left antenna. The left mandible was very small and drone-like in formation while the right was extended far beyond the middle of the clypeus. The large compound eye on the left side was like that of the drone while the other compound eye resembled that of a queen bee. The right antenna was typically female while the left was slightly longer with some of the segments fused near the tip. An examination of the proboscis showed that the characters of the two sexes were carried out on their respective sides with even the glossa shortened on the left side so that it curved in that direction. The left maxilla was abnormally short and was partly fused to the mentum, which probably explained why the bee would not partake of honey when it was offered. Fig. 128.

There was nothing strikingly abnormal about the development of the thorax proper except the dividing line through the dorsal middle portion. The hairs on each side of this line appeared different and accentuated the unnatural division. The left wings were somewhat longer and broader than the right pair and the right legs were typical of the worker while the left legs resembled those of the drone.

The abdomen was twisted slightly to one side at the last segment which kept moving in and out until the insect died, as above described. The line dividing the dorsal middle portion of the abdomen was made quite evident by a difference in the coloration of the second and third segments on either side of the line, the one being yellow while the other was almost black.

An examination of the internal anatomy of the abdomen revealed a honey stomach larger than that in a normal drone, a complete set of male reproductive organs somewhat overdeveloped, a spermatheca, a poison sac and a very primitive sting. Fig. 129. The ovaries were not discovered although they may have been destroyed during the removal of the above organs.

Interest in gynandromorphism in bees is increased by the rarity of its occurrence and by the possible evidence it may furnish as to the role of chromosomes in sex determination. Boveri, von Siebold and Englehardt were fortunate in securing a number of gynandromorphs in 1864 from a colony headed by a queen that produced gynandromorphs every three

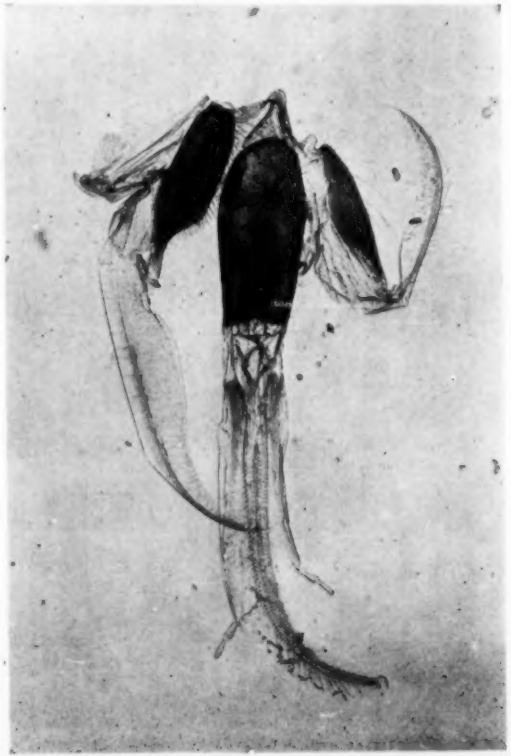

FIG. 128.—A view of the proboscis of the gynandromorph, the left side of which is male, the right, female.

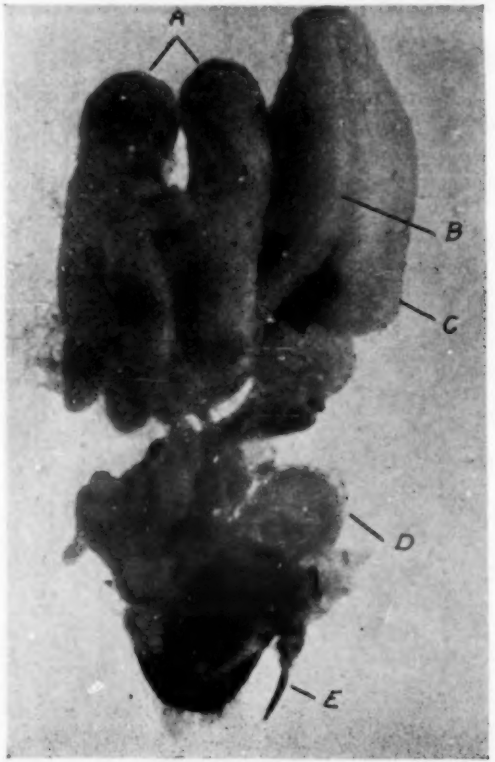

FIG. 129.—The reproductive organs found in the gynandromorph honeybee. A, B, C, portions of the male sex organs; D, the spermatheca, and E, the sting of the queen. The organs were twisted out of place for photographing.

weeks. Their study was made all the more interesting by the queen, which was an Italian, having been mated to a black drone. Boveri arrived at the conclusion that in gynandromorphs fertilization takes place after the first cleavage division and that only one of the first two cleavage-nuclei is fertilized. Others do not agree with this opinion but advance at least three other theories; one that the egg from which a gynandromorph develops contains two nuclei; or that a second spermatozoon enters and develops independently in an already fertilized egg (Morgan); or that one of the X-chromosomes is eliminated from one of the nuclei during an early embryonal mitosis in the female (Morgan). Morgan has shown the latter opinion to be a fact for Drosophila in the case of a bilateral gynandromorph. Goldschmidt and Katsuki in 1928 observed in certain crosses of silkworms the occurrence of inherited gynandromorphism in which many lateral gynandromorphs appeared in successive generations. A careful study of this race revealed that the gynandromorphs were double embryos of opposite sex fused in the median line to produce one animal. This evidence was supported by genetic and cytological findings of indisputable character.

An examination of the colony in front of which the present specimen was found, as well as the colonies on either side, revealed that there were no emerging drones. This seemed to indicate that the length of time that it took the specimen to develop may have been shorter than that of a normal drone. Repeated examinations of the same colonies have failed to produce any more specimens. All three queens were young and prolific and of good stock.

On another occasion (1916) the writer found drones with eyes of different color and at still another time (1921) a "cyclopic" bee, a worker with a single compound eye.

TEMPERATURE AND HUMIDITY IN RELATION TO HCN FUMIGATION FOR THE RED SCALE[1]

By H. J. QUAYLE and P. W. ROHRBAUGH,[2] *University of California Citrus Experiment Station*

Temperature and humidity have always been considered important factors in relation to plant injury in hydrocyanic acid fumigation. In the fumigation of citrus trees in California, the range of safe temperatures is usually considered to be between 40° and 80° F. Humidity is a less definite factor. Practical fumigators stop work when there is visible moisture on the foliage and when the tents become distinctly damp or are actually wet on account of high humidity. Low humidity in the citrus belt of California usually accompanies high winds or so-called "northers." In the actual path of such winds the wind itself is sufficient to stop fumigation, but outside the path of wind the atmosphere is calm and carries very little moisture. Relative humidity below about 30 or 40 per cent is considered unsafe for fumigation of citrus trees.

In the following studies an attempt has been made to evaluate the importance of temperature and humidity, particularly from the standpoint of the results on the insect, in this case the red scale, *Aonidiella aurantii* (Mask.). A preliminary study, however, is included as to the effect of the same factors on the plant, in this case rooted lemon cuttings.

The infested lemons were brought to the laboratory, placed in paper bags, and then put in the control cabinets at different temperatures and humidities. When ready for fumigation they were placed in wire baskets, which were hung in the fumatoriums. The fumatoriums used were two 100 cu. ft. capacity vacuum fumigators, which had complete air-conditioning equipment. All fruits were fumigated at atmospheric pressure. From 10 to 15 moderately infested lemons, of the same stage of maturity, were used in each fumigation, and from 24 to 33 separate fumigations are represented in each of the series in Table 1. Each series involves from 18,000 to 34,000 insects, and about 1,000,000 insects are included in the entire study. A 45-minute exposure of 2 cc liquid HCN, 96 to 98 degrees purity, was used in all of the fumigations tabulated unless otherwise indicated.

In the examination of scales for results, all stages preceding the second molt were eliminated. Two sets of controls were maintained: one that was conditioned and not fumigated, and the other neither conditioned nor fumigated.

[1]Paper No. 308, University of California Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

[2]Resigned, April 15, 1934.

TABLE 1. PERCENTAGE OF SCALES KILLED (LAST COLUMN) IN RELATION TO THE TEMPERATURE AT WHICH THEY WERE PRECONDITIONED (NEXT TO LAST COLUMN)

Series	Date 1933	Locality	Number fumigations	Total scales examined	Fumigated	Preconditioned R.H.	Preconditioned Temp.	Scales killed
					° F	*Per cent*	° F	*Per cent*
A	May	Glendora	9	4,835	75	55	80	89.2
			9	3,788	75	55	40	95.6
1	Oct.	Corona	15	14,456	70	70	90	73.0
			15	14,091	70	70	50	89.8
2	Oct.	Corona	10	8,002	70	70	90	85.7
			10	8,204	70	70	75	83.2
			10	7,450	70	70	50	93.5
3	Oct.	Corona	11	8,621	50	70	90	60.2
			11	9,808	50	70	75	79.5
			11	9,949	50	70	50	92.8
4	Oct.	Glendora	8	11,920	50	70	90	92.5
			8	11,029	50	70	75	97.2
			8	11,865	50	70	50	99.5
5	Oct.	Prenda	11	8,037	90	70	90	81.4
			11	1,117	90	70	75	84.9
			11	8,685	90	70	50	93.8
6	Oct.	Corona	6	7,646	70	70	90	78.2
			6	3,759	70	70	75	82.8
			6	5,987	70	70	50	97.2
7	Oct.	Prenda	11	10,455	75	70	90	66.0
			11	7,744	75	70	75	76.3
			11	9,555	75	70	50	94.3
8	Oct.	Prenda	8	7,212	90	70	90	78.6
			8	6,457	90	70	75	86.3
			8	5,705	90	70	50	92.4
9	Oct.	Prenda	8	5,861	90	70	90	89.8
			8	6,237	90	70	75	91.8
			8	6,481	90	70	50	96.9
10	Oct.	Prenda	8	7,993	50	70	90	85.0
			8	8,182	50	70	75	92.1
			8	6,660	50	70	50	97.7
11	Nov.	Prenda	8	8,416	90	70	90	87.8
			8	8,571	90	70	75	91.4
			8	8,014	90	70	50	97.4
12	Nov.	Corona	8	5,027	60	70	90	85.2
			8	5,440	60	70	75	87.8
			8	3,730	60	70	50	98.9
13	Nov.	Corona	8	11,118	70	70	90	76.3
			8	10,184	70	70	75	79.8
			8	11,005	70	70	50	92.5
14	Dec.	Corona	9	11,089	65	70	90	81.7
			9	11,343	65	70	75	82.4
			9	10,950	65	70	50	92.9
15	Dec.	Corona	8	11,064	70	70	90	78.8
			8	11,265	70	70	75	81.2
			8	10,662	70	70	50	95.4
16	Dec.	Corona	9	9,333	64	70	90	79.9
			9	8,472	64	70	75	79.7
			9	8,783	64	70	50	96.0
17	Dec.	Corona	9	8,213	56	70	90	87.6
			9	6,726	56	70	75	89.6
			9	7,587	56	70	50	98.3
18	Dec.	Corona	9	12,403	60	70	90	81.5
			9	10,810	60	70	75	81.2
			9	11,789	60	70	50	94.9

EFFECT OF TEMPERATURE ON THE INSECTS.—The first series of experiments consisted in fumigating red scale on lemons at different temperatures during the actual exposure only, the fruits having been brought from ordinary room temperatures. This series of experiments showed no significant difference in the red scale killed between a temperature range of 50° and 90° F.

The next series of experiments, conducted in May, 1933, consisted in the fumigation of scale-infested lemons which had been preconditioned by keeping them for a certain length of time in the air-conditioning cabinets at the temperature and humidity at which they were to be fumigated later. The preliminary series was preconditioned at 40° and 80° F, and fumigated at 70° to 79° F. The results throughout the first series of experiments were rather startling and unexpected, and they were so uniform that a comprehensive series of experiments was undertaken, the data of which are detailed in Table 1.

The infested lemons were preconditioned at three temperatures, 50°, 75°, and 90° F, with a relative humidity in each case of 70 per cent. The preconditioning was first carried on for a period of 16 hours; but, after certain experiments, it was found that the period could be reduced to 4 hours or advanced to 48 hours, without affecting the results. In the following experiments the preconditioning period ranged from 4 to 48 hours. The fruits were transferred directly from the conditioning chambers to the fumatorium. After the fumigation they were transferred to the greenhouse, where the humidity was kept rather high in order to prevent the fruits from drying preliminary to the examination of the scales two weeks later.

The attention of the reader is called particularly to the last two columns in Table 1, headed "Preconditioned" and "Scales killed." It will be noted that, without exception, the scales preconditioned at 50° F showed a higher mortality than those preconditioned at a temperature of 90° F, and in practically every case there was a higher mortality where the scales were preconditioned at 75° F than at 90° F. These facts hold, regardless of the temperature during the actual fumigation.

The increase of percentage killed where the insects were preconditioned at 50° F, as compared with 90° F, ranged in the different series from 2.3 per cent in series 4, to 18 per cent in series 7.

MINIMUM CONDITIONING PERIOD.—In Table 1, the periods of conditioning ranged from 4 to 48 hours. An experiment was conducted to determine the effect of a period of conditioning less than 4 hours. The results of this experiment are given in Table 2. The preconditioning

temperature in this case was 50° F, the fruits having been brought from room temperature; they were fumigated at 65° and 70° F.

TABLE 2. RESULTS OF EXPERIMENTS TO DETERMINE THE MINIMUM PERIOD OF CONDITIONING

Period of conditioning	Temperature of preconditioning	Temperature of fumigation	Scales killed		Total scales examined	
			Series 1	Series 2	Series 1	Series 2
Hours	*° F*	*° F*	*Per cent*	*Per cent*		
4	50	65–70	89.4	83.6	9,672	8,530
1	50	65–70	85.8	81.7	8,711	7,487
0	50	65–70	76.8	70.5	9,976	7,487

The data in Table 2 show a decreased kill when the conditioning period is less than 4 hours.

Lemons taken from room temperature and placed in cabinets at 50° F required about 4 hours to be cooled throughout to the cabinet temperature. The volume of substance in the fruit allowed only a slow rise in temperature when the lemons were placed in the higher temperatures of the fumatorium. An effort was made to determine if preconditioning infested leaves and twigs would show the same effect on the scales as preconditioning the fruit; for in the latter case the effect of the cooling is more lasting. The experiments showed no significant difference in the fumigation results on preconditioning the leaves and twigs, but the tests were scarcely extensive enough for reliable conclusions. To determine whether temperatures lower than 50° F would show a still greater difference in effect on fumigation results, a series of experiments included the preconditioning of infested fruits at 35° F and 50° F. The results are shown in Table 3.

TABLE 3. THE EFFECT OF PRECONDITIONING AT 35° F AS COMPARED WITH 50° F

Temperature for preconditioning	Temperature for fumigation	Scales killed	Total scales examined
° F	*° F*	*Per cent*	
50	60	71.3	7,762
35	60	69.4	8,022

THE EFFECT OF HUMIDITY ON THE INSECTS.—One series of experiments was carried on to compare the effect of fumigating at a relative humidity of from 50 to 59 per cent, and from 80 to 89 per cent. No significant difference was shown in the percentages of red scale killed when the humidity ranged from 50 to 59 per cent as compared with 80 to 89 per cent, the temperature in either case being 65° F. As between the extremes of humidity, however, there seemed to be a consistent difference in the fumigation results, as shown in Table 4.

TABLE 4. THE EFFECT OF HIGH AND LOW HUMIDITY ON FUMIGATION RESULTS

Relative humidity	Temperature	Scales killed	Total scales examined
Per cent	° *F*	*Per cent*	
90	70	69.4	2,914
52	70	81.8	2,846
93	70	77.2	3,157
40	70	85.2	1,859
90	71	77.9	2,366
33	70	82.8	2,456
100	70	81.8	3,519
22	72	86.3	3,939
100	58	66.1	3,319
40	60	87.6	2,792
100	70	69.4	2,734
41	71	78.2	2,352
Averages 90–100	58–71	75.7	18,009
22–52	60–72	85.9	16,244

The above series (Table 4) is given in full to show that there was a consistent difference in all of the fumigations in favor of the low relative humidity as compared with the very high relative humidity (90 to 100 per cent). It will be recalled that the above comparison was made in a

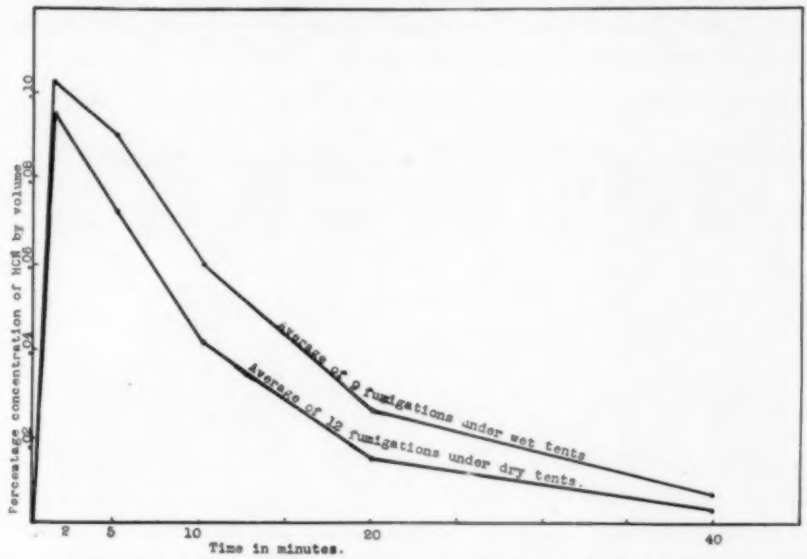

Fig. 130.—Graph showing comparative concentrations of HCN under dry and wet tents over identical form trees.

gas-tight fumatorium. In the case of tent fumigation, another important factor must be considered, namely, the effect of high humidity in decreasing tent leakage.

In citrus fumigation high humidity is a limiting factor, not only on account of the mechanical difficulties involved but also because of the increased concentration of gas through less leakage in the case of wet tents. In order to determine the difference in gas concentration under a wet as compared to a dry tent, fumigations were conducted under form-trees. In one case the tent was thoroughly wetted on one side by means of a water spray. The condition imposed no doubt exaggerated even the extreme of high humidity conditions. The form-trees, of identical size and shape, were given an 18 cc schedule, and determinations of the gas concentration were made at 2, 5, 10, 20, and 40 minutes after the charge was made.

The graph (Figure 130) gives the average gas concentration, at the different intervals, of all of the fumigations under the wet and under the dry tents. It will be noted that, while the average gas concentration is higher at each interval following the fumigation charge under the wet than under the dry tent, the decrease in concentration is practically the same in both cases. The gas was probably absorbed by the moisture on the wet tent at about the same rate it escaped through the fabric in the case of the dry tent. Table 5 gives the average mean gas concentration, in per cent by volume, following each fumigation.

TABLE 5. AVERAGE MEAN CONCENTRATION OF HCN UNDER WET AND DRY TENTS, IN PER CENT BY VOLUME

Wet tents: 9 fumigations	Dry tents: 12 fumigations
0.1196	0.0721
.1119	.0748
.1071	.0484
.0816	.0688
.0912	.0984
.0840	.0684
.0965	.0603
.0843	.0689
0.0738	.0704
	.0607
	.0604
	0.0538

EFFECT OF TEMPERATURE ON THE PLANT.—Potted seedling orange trees were first used to determine the effect of temperature on the plant, but there is so much variation in such potted seedlings that the results were too erratic to furnish reliable data. Rooted lemon cuttings were then used. Lemon twigs about six inches long, half the size of a lead pencil, and having four leaves, were secured from similar trees in a particular plot. These were rooted in sand with underground heat. In about two months these cuttings had rooted sufficiently to be transferred to six-inch flower pots where they were allowed a month or more to become well

established. These potted cuttings were then used in the fumigation experiments; thus the variability of seedlings was overcome in a large measure.

The first series of experiments included the preconditioning of the plants for 16 hours, at temperatures of 50° and 90° F, with a relative

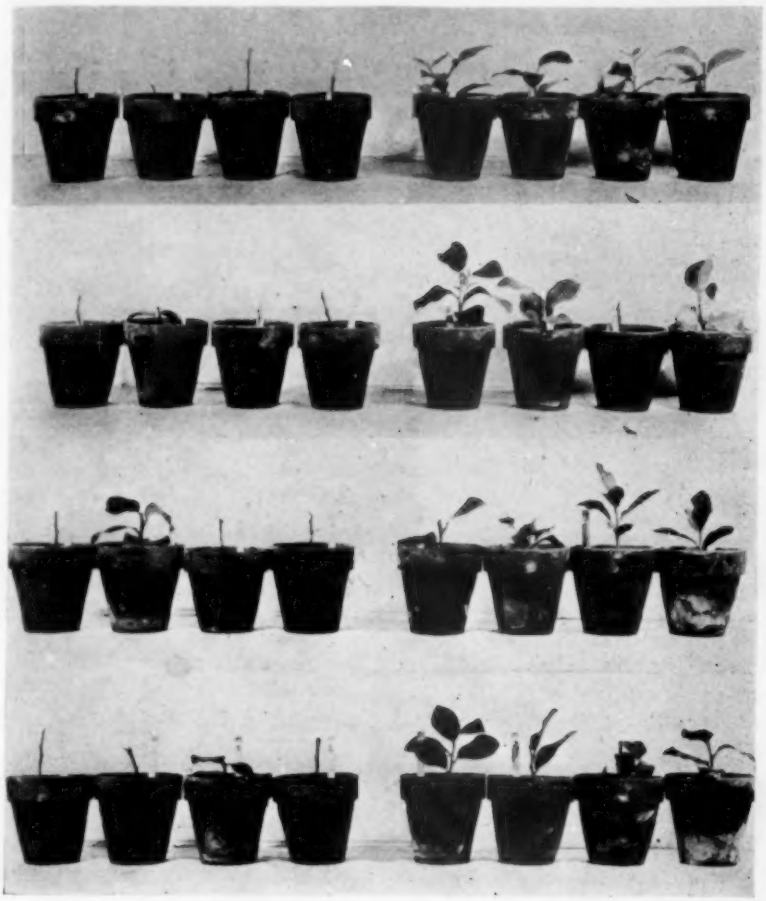

Fig. 131.—The four rooted lemon cuttings on the left in each case were preconditioned and fumigated at a temperature of 50° F and a relative humidity of 70 per cent. The four plants on the right in each case were preconditioned and fumigated at the same relative humidity but at a temperature of 90° F. The dosage was 30 cc of HCN for 45 minutes in a 100 cu. ft. fumatorium. Thirteen plants were defoliated at 50° F, and one at 90° F. Sixty days after the fumigation, eight plants were dead at 50° F, and none at 90° F.

humidity of 70 per cent. The actual humidity, however, ranged from 70 to 75 per cent. The same conditions were imposed in the fumigation chamber during the 45-minute period of exposure. The fumigation dosage used in this set was 30 cc of liquid HCN. The results of this series of

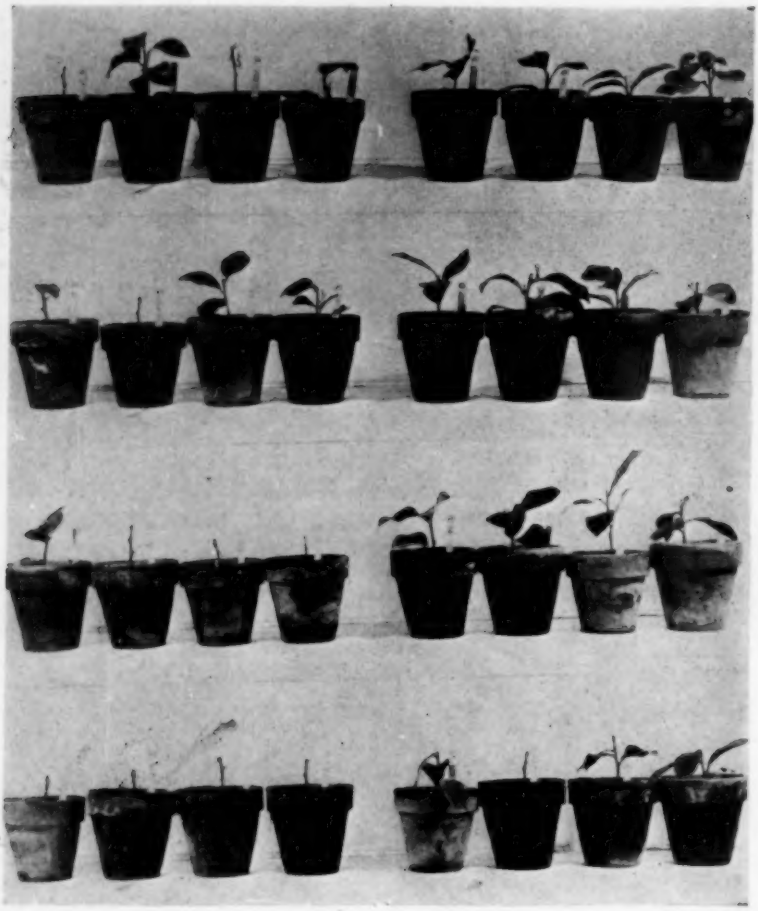

Fig. 132.—The four rooted lemon cuttings on the left in each case were preconditioned and fumigated at a temperature of 90° F, and a relative humidity of from 34 to 42 per cent. The plants on the right in each case were preconditioned and fumigated at the same temperature but at a relative humidity of from 85 to 90 per cent. The fumigation dosage in the upper two rows was 40 cc and in the lower two rows 60 cc of HCN for 45 minutes in a 100 cu. ft. fumatorium. Ten plants were defoliated at the low humidity, and one at the high humidity. Sixty days after the fumigation, six plants were dead at the low humidity and one at the high humidity.

experiments are shown in Figure 131. In each case the four plants on the left were conditioned and fumigated at a temperature of 50° F, while the four on the right were conditioned and fumigated at a temperature of 90° F, the relative humidity being the same in both sets. At 50° F there were 13 plants defoliated, as compared with 1 defoliated at 90° F.

EFFECT OF HUMIDITY ON THE PLANT.—The second series was subjected to the same temperature of 90° F, with a variation in the humidity. It was intended to show the humidity at 35 per cent and 90 per cent, respectively; but the actual humidity ranged from 34 to 42 per cent and from 85 to 90 per cent, respectively. The results of this series are shown in Figure 132. The fumigation dosage used in this series was 40 cc of liquid HCN for the upper two rows, and 60 cc for the lower two rows. The four plants on the left were under conditions of low humidity in each case, and the four on the right were under high humidity. Ten plants were defoliated under the low humidity, while one was defoliated under the high humidity, the temperature being the same in both cases.

The third series was subjected to a temperature of 50° F instead of 90° F, with about the same humidities as in the second series. The actual humidities ranged from 27 to 40 per cent in one set, and 80 to 85 per cent in the other set. In all tests of this series, 60 cc of HCN were used.

The results of this series are shown in Figure 133. In each case the four plants on the left were under low humidity conditions, while the four on the right were under high humidity conditions, the temperature in each case being at 50° F. It will be noted that under low humidity fifteen plants were defoliated, while under high humidity two plants were defoliated and three partially defoliated. The total injury under both sets of conditions was rather more in this series, which may be accounted for by the high dosage (60 cc) used. Dosages of 30 cc, 40 cc, and 60 cc of HCN, used in an absolutely tight fumatorium for 45 minutes, represents very heavy charges. In the first series of 30 cc of HCN were used, but when two or three days had elapsed after the fumigation and no injury was evident, the dosage was increased for the other series. It has since become apparent that it would probably have been better if 30 cc had been used throughout. On a few of the lemon cuttings there was some new growth, but for the most part the foliage consisted of old, mature leaves. These were not burned, a phase of injury that appears soon after the fumigation, but simply dropped from the plant several days later.

EFFECT OF DRY AND WET SOIL.—One series of lemon cuttings was fumigated to determine the difference, if any, between wet and dry soil. The actual moisture content was not determined. The soil in one set was

very dry, but the plants were not wilted; and in the other set the soil was thoroughly wet. Four fumigations are represented, in each of which a dosage of 60 cc of HCN was used for 45 minutes, with a temperature of 65° to 70° F and a relative humidity of 40 per cent. The four plants on

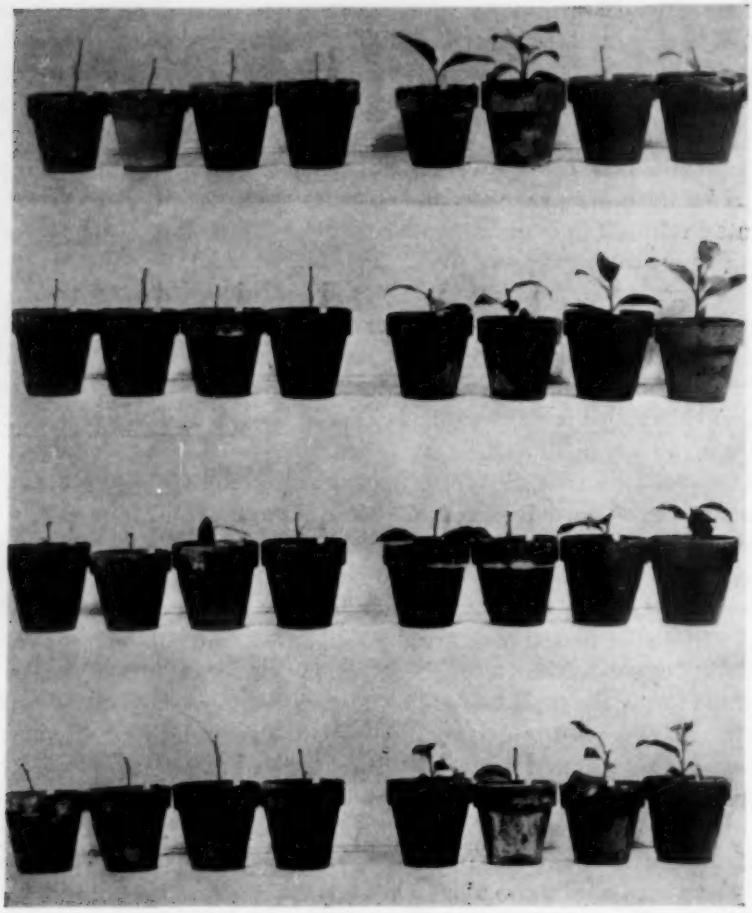

Fig. 133.—The four rooted lemon cuttings on the left in each case were preconditioned and fumigated at a temperature of 50° F, and a relative humidity of from 27 to 40 per cent. The four plants on the right in each case were preconditioned and fumigated at the same temperature but at a relative humidity of from 80 to 85 per cent. The fumigation dosage was 60 cc of HCN for 45 minutes in a 100 cu. ft. fumatorium. Fifteen plants were defoliated at the low humidity, and two defoliated and three partially defoliated at the high humidity. Sixty days after the fumigation, fourteen plants were dead at the low humidity and one at the high humidity.

the left (Figure 134) in each case were in dry soil, and the four on the right in wet soil. Out of the sixteen plants in the dry soil, fifteen were defoliated and one partially defoliated. Out of the sixteen plants in the wet soil, six were defoliated and four partially defoliated. Thirty days later nine plants were dead in the dry soil and four in the wet soil. It is

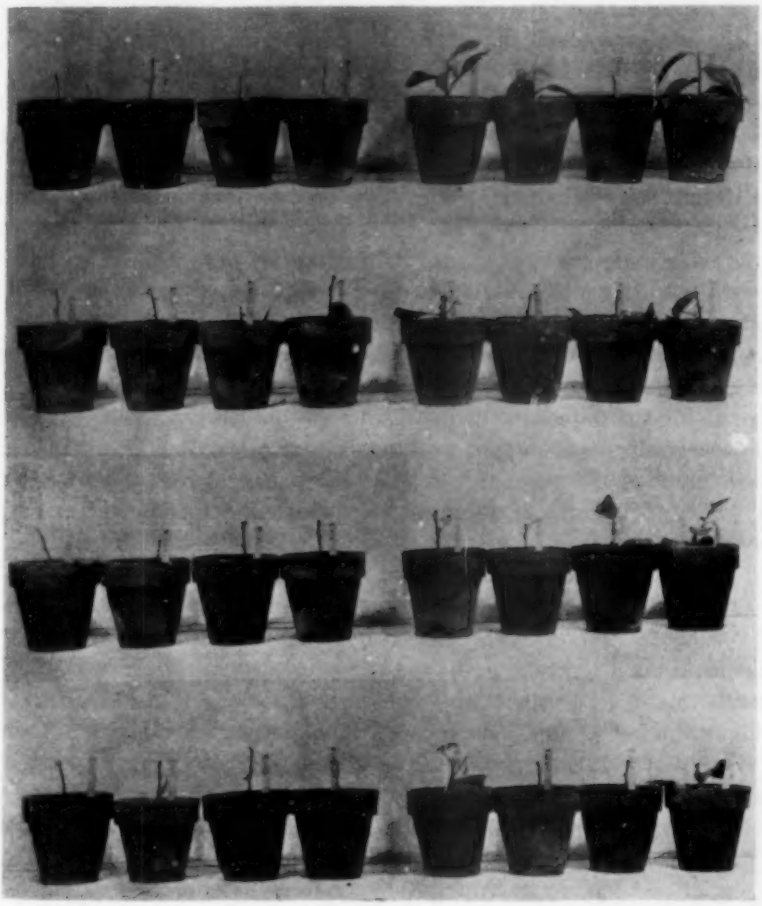

Fig. 134.—The four rooted lemon cuttings on the left in each case were in dry soil, and the four on the right in each case were in wet soil at the time of fumigation. The dosage was 60 cc of HCN for 45 minutes in a 100 cu. ft. fumatorium. Sixteen plants in the dry soil were defoliated, and six defoliated and four partially defoliated in the wet soil. Sixty days after the fumigation, ten plants were dead in the dry soil and four in the wet soil.

likely that a smaller dosage of HCN would have brought out a still greater difference between the dry and wet soils.

DISCUSSION.—The effects of temperature and humidity on fumigation injury of the lemon cuttings as brought out in these experiments have been in general contrary to what was expected. In practical citrus fumigation experience there is greater injury with higher rather than lower temperature. Less injury occurs from winter than from summer fumigation in California, even though higher dosages are generally used in the winter. Differences in the reaction of the plant to humidity as brought out in these studies in comparison with tent fumigation, may be explained by the tightening of the tent under conditions of high humidity. In the case of dry and wet soils, it is generally recognized that fumigation is preferred on soils rather too dry than too wet. The limited experiments along this line in this study gave a contrary result. These experiments were rather aside and not a part of the planned program of the relation of temperature and humidity to fumigation, hence the desirability of more extensive data.

It is possible that the dormancy of the tree is a greater factor in resistance to HCN than temperature at the time of fumigation, which would account for the difference in the results of this study as compared with practical citrus tent fumigation. The difference in reducing sugars at different times of the year and at different temperatures and humidities may account for some of the results. Studies under way in certain irrigation investigations indicate that there is a water deficit in citrus trees in cold as well as in dry soils. Whether it is a water relation, differences in the amount of reducing sugars, or some other factors that may be responsible for the results recorded on the plants in this paper, are questions for further study.

SUMMARY.—1. Temperatures between 50° and 90° F, during the actual period of fumigation exposure only, made no significant difference on the kill of red scale.

2. Temperatures to which the scales on lemon fruits were subjected previous to the fumigation had a marked effect on the fumigation results.

3. With active insects a higher temperature at the time of HCN fumigation, or previous to the fumigation, is generally conceded to result in a higher percentage of kill.

4. In the case of the red scale, as indicated by these studies, conditioning at low temperatures results in a higher percentage of kill by fumigation.

5. No significant differences were indicated in these studies as to the effect of humidity, within a range of from 50 to 80 per cent, on fumigation results on the red scale

6. In the case of high relative humidities, 85 to 100 per cent, there was a decrease in fumigation results as compared with low relative humidities of from 27 to 40 per cent.

7. In tent fumigation there is generally considered to be an increase in kill through the tightening of the tent in case of high humidity.

8. Gas concentration studies under wet and dry tents indicated a greater concentration under a wet tent, but the decrease in concentration was about the same in each case, due probably to the absorption of gas by the wet tent corresponding to the escape of gas through the dry tent.

9. At a relative humidity of 70 per cent, there was greater injury to the plants when they were preconditioned and fumigated at a low temperature (50° F) than at a high temperature (90° F).

10. Where the soil was allowed to become very dry, without the plants wilting, as compared with very wet soils, a greater number of rooted lemon cuttings were injured in the dry than in the wet soils.

A CRITICAL EXAMINATION OF TWO PAPERS ON MOTH REPELLENTS

By Glenn W. Herrick

In view of the far-reaching industrial effect that the conclusions set forth in two recent papers on clothes moth repellents may have, it is important to examine in some detail the experiments described in those papers.

In a paper entitled, "Paradichlorobenzene, naphthalene, and the cedar oils inefficient as repellents against clothes moth adults," which appears in the Journal of Economic Entomology, Vol. 27, page 401 (1934), the author states, "It was shown by L. J. Bottimer in 1929 that paradichlorobenzene and naphthalene would *not* repel moth larvae." The italics are mine. This is an incorrect, inferential statement of the results and conclusions of Bottimer's experiments. Bottimer has told us what he showed regarding this problem in his paper, "Notes on paradichlorobenzene and naphthalene as repellents against clothes moth larvae," Jour. Ec. Ent., Vol. 22, p. 570, 1929.

The accompanying diagrams show at a glance the plan and method of Bottimer's experiments. Two ounces of paradichlorobenzene were placed on a large sheet of paper on the floor of a room 9 x 16 x 10 (1440 cu. ft.). The toxic effect on any insect of this small amount of paradichlorobenzene in so large a room is nil and need not be considered. The larvae in the experiment were placed at X (Fig. 135) within the circle of tangle-

foot between the pieces of flannel A and the pile of paradichlorobenzene. Now what did the larvae do? How did they react? Consider test No. 1. All of the larvae moved *away* from the paradichlorobenzene, 44% of them stopping beneath flannels A because the gas had only an annoying, not a toxic effect on them, 11% moved 12 inches away to flannels B, 11%

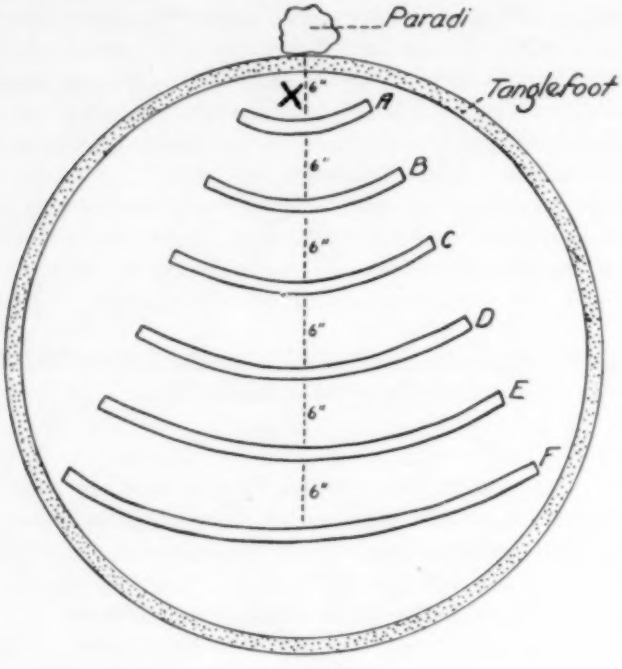

FIG. 135

more active and more annoyed by the paradichlorobenzene moved 18 inches away to flannels C, 11% more annoyed, moved 24 inches away to flannels D, while 22% moved 30 inches away to flannels E, nearly as far as they could get from the paradichlorobenzene. The movements of the larvae in the other tests were comparable, in some tests the larvae were more active in their efforts to get away from the paradichlorobenzene while in other tests they were not so eager.

The tests with naphthalene (the author doesn't tell us how much he used but we infer 2 ounces), show comparable results, perhaps in most tests not os striking as with the paradichlorobenzene because naphthalene volatilizes much more slowly and the concentration of gas was not so great at any one time.

The third experiment is even more striking. The larvae were allowed to settle and become at home under an inch band of flannel, 8 inches in diameter. Two ounces of paradichlorobenzene were then placed in the middle of the flannel circle (Fig. 136). How did these permanently settled larvae on which the small amount of paradichlorobenzene exerted no toxic effect, react? From 14% to 80% of them, within 48 hours, tore

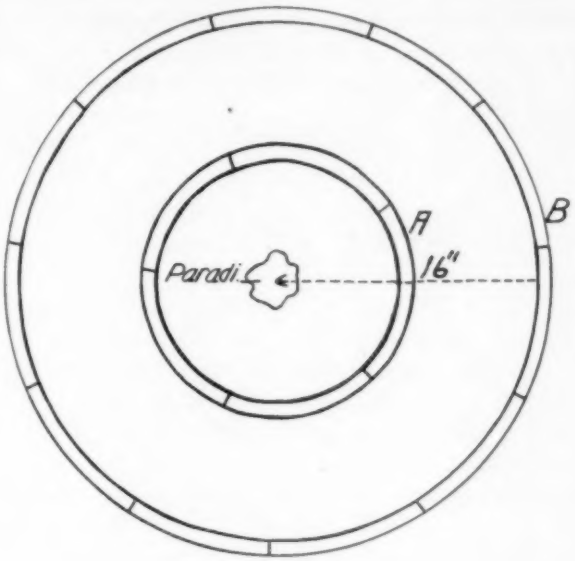

FIG. 136

themselves away from their permanent location under flannel A and moved away from the paradichlorobenzene to flannel B, as far away as they could get and still find food and a hiding place.

Let us briefly summarize the outstanding results of Bottimer's experiments.

1. Not a single larva moved *toward* the paradichlorobenzene or naphthalene.

2. Every larva moved *away* from the annoying materials, many of the more active ones as far away as they could get.

3. The number of larvae used in each test, about 7 on the average, is so small that the data on their behavior are of doubtful significance.

4. But one conclusion can be drawn from these experiments, namely, that paradichlorobenzene and naphthalene are repellent to the larvae of clothes moths. This is the more apparent when the small amounts of

the crystal are considered together with the wide dispersion and weak concentration in this large room of the tiny volume of gas emanating from each pile of fumigant.

It is now of interest to examine the paper by Billings, "Paradichlorobenzene, naphthalene and the cedar oils as repellents against clothes moth adults." The experiments were performed by tieing pieces of flannel over the mouths of 4-ounce bottles, each bottle nearly full of the particular fumigant. It must be noted that each piece of flannel was large and

FIG. 137

the loose portions of each extended for several inches beyond the area directly over the mouth of the bottle, like a flaring skirt (Fig. 137). Because of the small size of the bottles and rather large pieces of cloth, one could believe that the edges of the flannel might nearly touch the raw wool on which each bottle stood and into which probably each bottle sunk some little distance of its own weight. Eggs were laid by the moths on the undersides of the portions of flannel projecting beyond the mouths of the bottles. Larvae lived on the underside of the flannel and it must be remembered that this surface of the cloth was near the raw wool and well removed from the openings of the bottles.

Two or three conditions in the experiments are of vital importance: (1) the surface area over which volatilization of each fumigant could take place was very small—the area of a cross-section of the bottle; (2) in ad-

dition, the flannel over the mouth of each bottle would act, to some extent, as a cork in preventing volatilization of the fumigant; (3) it is evident, therefore, that the amount of gas emanating from each fumigant and seeping through the flannel was exceedingly small.

If the moths remained active in the box and kept on laying eggs in the raw wool, there is no reason to suppose that they would not lay eggs on the underside of the flannel, a region close to the wool and comparatively far from the weak odors of the fumigant. The odor of any one fumigant, as it issued from the mouth of the bottle, quickly dissipated itself in every direction. It is difficult to see how the odor could have reached the undersides of the flannel in any appreciable amount.

The significant phase of the experiment is the fact that no moths laid eggs on the flannel over the mouths of the bottles and apparently nowhere on the upper side of the flannel. It is true that moths tend to enter folds in clothing and, in general, to hide. On the other hand, the larvae in dark closets and boxes work on all sides of woolen fabrics. Only a few days ago the writer took down a hat which had lain unused on a shelf in an ordinary clothes closet. The upper surface of the crown and brim was badly eaten by larvae and several of them were still present.

We must conclude that the data of this experiment are wholly inadequate to prove the thesis of the author. Indeed, there is evidence from the data that the materials used were actually repellent to the moths. Some form of technique very different from that used by the author must be devised in order to obtain reliable results.

The effect on certain trade industries of the two papers under discussion may well be far-reaching and unjust. For instance, if cedar oil is not repellent to clothes moths then cedar chests have no particular value. A good basswood box equally well made with two or three tablespoonfuls of paradichlorobenzene in it to kill any eggs and larvae which may happen to be present, would be as good as a cedar chest and very much cheaper. Again, if on the basis of the erroneous conclusions in these papers, certain regulatory bodies in our Government were to impose strict regulations on certain trades, the result might be most unjust and disastrous.

Scientific Notes

Another Species of Thrips on Citrus Fruits. On January 23, 1934, a species of thrips was seen in great numbers on citrus fruits in a few groves in the vicinity of Hemet, California. The species was seen on Valencias, grapefruit and lemons, but were most abundant on navels. Many occurred in the navel, probably because of the protection afforded. The feeding on the fruit resulted in markings of irregular form and size and of a light yellow color in contrast to the general orange color of mature oranges at this season. Young larvae were observed, indicating that eggs were deposited somewhere on the tree. By the middle of February, the numbers were greatly reduced. More mature larvae were seen on this date than on the first visit. The species was identified by Mr. Dudley Moulton as *Frankliniella gossypii* Morgan. Mr. Moulton stated that the only host plant heretofore recorded for this species was cotton. No important plantings of cotton occur nearer than the Coachella Valley, which is forty or fifty miles away and separated by an extensive mountain range. Cotton waste has been used to a limited extent in the Hemet Valley. This species of thrips has not been recorded, however, as attacking citrus in the Coachella and Imperial valleys of California, or in Arizona and elsewhere where cotton is extensively grown.

H. J. QUAYLE, *Entomologist, University of California Citrus Experiment Station, Riverside, California.*

An Artificial Food Medium for the Mediterranean Fruit Fly (*Ceratitis capitata* Wied.) During the course of laboratory toxicity studies on the Mediterranean fruit fly (*Ceratitis capitata*) an artificial medium has been developed which can be used as a food for adult flies and, when modified, serves as a medium for the rearing of larvae. The food medium is a non-fermenting mixture composed of 2 cc. extracted honey, 4 cc. crushed papaya, 3 cc. water, 1 gram brown sugar and .16 gram bacto-agar-agar. After preparation, it should be auto-claved at 15 pounds' pressure for 20 minutes. The utilization of food of this type for flies in cages decreases the time required for their care, for when fresh cut fruits or fruit juices are used they must be changed every day or two because of fermentation, decay, and drying out of the cut surfaces. The medium is as attractive as fruit juices and will last from 6 weeks to 4 months, depending upon the size of the feeding population.

Adult female flies were observed to oviposit in the food medium in the cages but the mixture was too stiff to permit free movement of the young maggots. However, when the quantity of agar-agar in the medium was reduced to 0.10 gram, the larvae were able to move freely through the medium and the development was normal. Over 300 larvae were successfully reared through to maturity from fertile eggs placed in the medium. This method may be standardized for the rearing of fruit fly larvae under laboratory conditions and the medium used in studying the activity and development of the larva. No doubt the juice of other fruits can be substituted for the papaya juice where papayas are not obtainable.

RALPH H. MARLOWE, *Bureau of Entomology, U. S. Department of Agriculture, Honolulu, T. H.*

Food Plant Studies of the Chinch Bug. From May 20 to August 7, 1934, rearing experiments with the chinch bug were carried on. Eggs collected in the field were hatched in pill boxes, and the first instar bugs were colonized on the stems of food

plants. The plants for use were germinated from seeds planted in sand and then transferred to 100 cc. test tubes three-quarters filled with Pfeffer's nutrient solution.[1] The stem of each plant food was held in place in the neck of a test tube by a cotton plug; a small cavity, into which the chinch bugs were introduced, was left in the cotton plug around part of the plant stem.

A mean temperature of 86.7° F. and a relative humidity of 58% were maintained in the insectary in which the rearing was done. As the humidity was undoubtedly higher in the rearing tubes than in the surrounding air, the humidity was measured by determining the moisture content of the air in the tubes, as was indicated by the dialectric leakage currents across a very small air-dialecrtic condenser suspended in the tubes. The relative humidity was between 80 and 90%. Two 1000 watt lights supplied 1000 foot candles of illumination (.1 of standard Solar illumination) 24 hours daily, and, as practically all sunlight was excluded from the insectary, the illumination reached only 1600 foot candles at noon in late July.

The bugs were reared from the egg to the adult on the following plants: Bermuda grass, timothy, Kentucky blue grass, corn, meadow foxtail grass, chinch bug resistant sorghum, reed canary grass, Hungarian millet, wild barley, quack grass, Washington creeping bent grass, *Andropogon scoparius*, and Sudan grass. Under the same conditions, it was impossible to rear the chinch bugs past the first instar on alsike clover, white clover, sweet clover, buckwheat, alfalfa, soy bean, mangel wurtzel and lettuce.

The median time for the bugs to develop from the first instar to the adult on the grasses follow: Bermuda grass, 33 days; timothy, 35.6 days; Kentucky blue grass, 35 days; corn, 33.3 days; meadow foxtail grass, 36 days; chinch bug resistant sorghum, 36.3 days; Reed canary grass, 36.1 days; Hungarian millet, 36.2 days; wild barley, 35.2 days; quack grass, 35.5 days; Washington creeping bent grass, 37 days; *Andropogon scoparius*, 36 days; and Sudan grass, 34.3 days. It can be seen that there is no significant difference in the time required for the chinch bug to develop on any of the grasses used.

Of the bugs being reared on the grass plants, 17% died. None of the plants died during the time the chinch bugs were living on them.

B. D. BURKS, *University of Illinois*

Difference in Action of Derris and Pyrethrum Against the Imported Cabbage Worm Shown by Experiments with Gelatin Films Containing These Plant Materials. A piece of tinned sheet metal was dipped into a 10% aqueous solution of edible gelatin, drained, and allowed to dry at room temperature. The gelatin adhering to the plate was stripped off in the form of a transparent, paper-like film. A disk, ⅛ inch in diameter, was cut out of the film by a cork borer and was pressed between two moistened cabbage-leaf disks of the same size, thus forming the middle layer of a cabbage-leaf sandwich. These sandwiches were eaten readily by full-grown imported cabbage worms, *Ascia rapae* L., which were not affected by the gelatin consumed.

When the sheet metal was dipped in a 10% solution of gelatin containing 0.7% of high-grade derris or pyrethrum powder in suspension, the resulting dry film contained particles of the plant material well embedded and distributed in it. Cabbage-leaf sandwiches containing derris-gelatin and pyrethrum-gelatin films were made as described above. The feeding tests were made in Petri dishes, one mature cabbage worm and one sandwich being placed in each dish. As the particles of derris and pyre-

[1] McColloch, J. W. A., "A method for studying the Hessian fly and other insects," *Annals of the Entomological Society of America*, *14*, 227–30, 1921.

thrum were covered both by gelatin and by the leaf layers of the sandwich, no external surface of the larvae, except the mouthparts, could come in contact with the particles. The larvae ate a very small portion of the derris-gelatin film and usually died within 24 hours, but they were not killed by the pyrethrum-gelatin film, upon which they fed until the sandwiches were entirely consumed. Thinking that the gelatin might have prevented the pyrethrum from exerting its toxic effects within the alimentary tract, the writer made additional experiments by the ordinary sandwich method in which leaf disks were dusted with pyrethrum and sandwiches made with starch paste as the adhesive. By masking the periphery of the disks while they were being dusted, the edge of the sandwich was kept free from particles of pyrethrum. Again the larvae consumed entire sandwiches without being poisoned.

The contact action of the same derris-gelatin and pyrethrum-gelatin films was then studied. The films were formed in the tops and bottoms of Petri dishes by pouring a shallow layer of the suspension of the plant material in gelatin solution into the dishes and allowing it to dry. Larvae were allowed to crawl in these dishes. Untreated leaves were supplied at the end of six hours. The results obtained in the stomach tests were reversed in the contact tests. The larvae were rapidly affected by contact with pyrethrum-gelatin film and died within 24 hours. Those crawling on the derris-gelatin were not affected within 24 hours and most of the larvae were normal at the end of two days.

In summary, under the conditions of these experiments derris acts as a powerful stomach poison against the imported cabbage worm and pyrethrum as a potent contact poison.

Impregnated gelatin films were devised by the writer chiefly for studying the effect of light on the toxicity of thin deposits of derris and pyrethrum powders. Experiments on this subject are in progress.

M. C. SWINGLE, *Control Investigations, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Takoma Park, Md.*

Nicotine Kills Codling Moths. While applying nicotine sprays for codling moth control in late May, the writer observed numbers of moths flying from the apple trees. In one heavily infested orchard I wrote at the close of the day's work, "Codling moths were so numerous to-day that they flew out of the trees and rode on the sprayer while we sprayed. I have never before observed this phenomenon." On the following day more careful observations revealed that the moths were leaving the trees which were receiving sprays in which nicotine was liberated, and that most of the moths in coming from the trees were confused or sick and either flew or dropped to the ground. Apparently many of the moths were killed by the spray.

On June 8, while spraying in a heavily infested orchard, a sheet (10 x 12 ft.) was placed under the west half of an apple tree adjoining the packing shed on the west side. It was known that moths were emerging from the shed in considerable numbers. The following materials were used in 100 gallons of water and were added to the tank in the order given: 2 pounds copper sulphate, 5 pounds Black Leaf-155, 6 pounds hydrated lime, and 3 quarts Orthol-K oil emulsion. Pressure used in spraying, 325 pounds. Temperature 65, cloudy and slight breeze from the south. Within the first hour after spraying, a total of 65 moths fell on the sheet. Subsequently 12 more were taken from the sheet. These 77 moths were placed on a metal tray for observation and only 6 moths revived and escaped. A few lived a couple of days before dying but the majority were dead when picked from the sheet or died soon after. The moths which lived a day or two appeared to have suffered paralysis of the wings and were incapable of flight.

On June 20 the above test was repeated on the same tree. At this time moth flight had been greatly reduced but it was still taking place. A total of 27 moths fell on the sheet (12 x 15 ft.) and of these only 4 revived and escaped from the metal tray on which they had been placed for observation. Three hours and 20 minutes after the first spraying, the tree was sprayed again, but this time with double the dosage of nicotine. No moths dropped on the sheet or were observed leaving the tree, indicating that the first spraying had cleared the tree of its moth population.

Only volatile or free nicotine appeared to kill moths. Fixed nicotine (nicotine bentonite or nicotine sulphate with oil) was not effective. Nicotine was liberated by the addition of lime to the spray containing fixed nicotine. From our experience this year it is known that the same effect can be obtained when the quantity of lime does not exceed 3 pounds per 100 gallons with 5 poinds of nicotine bentonite (8% nicotine).

The data indicate the possibility of killing 85 to 90 per cent of the moth population in the trees at the time of spraying.

W. S. HOUGH, *Va. Experiment Station, Winchester, Va.*

A Note on Barium Fluosilicate Injury to Dahlia Flowers and the Results of a Test to Determine the Toxicity of this Material to Blister Beetles. On August 9, 1933, a severe infestation of the margined blister beetle (*Epicauta marginata* Fab.) was observed causing considerable damage to a small commercial patch of dahlias near Portsmouth, Va. Several of the insects were observed feeding on each flower and injury was severe. The grower had attempted to hand-pick the insects, but they reappeared in such numbers after each picking that control by this method was abandoned.

On August 9, at 4 p. m., the writer dusted several rows of the plants with a mixture of 80% barium fluosilicate and wheat flour, equal parts by weight. A light application of the dust was made with a 2-quart-capacity hand duster, special effort being made to direct the material to the flowers upon which the insects were congregated. In order to check up on the results one row in the center of the patch was left untreated. The temperature at the time of the treatment was 85° F. and the relative humidity 73%. The plants were examined on August 14 and it was observed that the barium fluosilicate-flour dust had severely burned the dahlia flowers. The injury was so severe that the flowers were unmarketable.

Just after dusting the plants on August 9 a total of 50 beetles were collected from the flowers and placed in a cage in the insectary without food. Two days later all of the insects were dead, while none of the beetles collected before the treatment, and caged without food, died. Only a few dead beetles were found beneath the plants when the field was visited five days after the treatment. The insects had apparently either crawled away and died or were repelled by the material, as very few live beetles were found on either the untreated or the treated plants.

The results of the experiment indicate that the barium fluosilicate-flour combination is toxic to the insects but that there is considerable risk of severe insecticide injury resulting from the use of the material on dahlias in eastern Virginia.

L. W. BRANNON, *Assistant Entomologist, Bureau of Entomology, U. S. Department of Agriculture*

Notes on the Occurrence of the European Weevil, *Tychius* (*Miccotrogus*) *picirostris* Fab., in Western Washington. One specimen swept from clover in 1929 and two others collected on the same host in 1931, from Puyallup, Wash., were sent to L. L. Buchanan, Bureau of Entomology, U. S. Department of Agriculture, Washington,

D. C., and determined by him as the true *Tychius picirostris* Fab. However, Mr. Buchanan's label was written as *Tychius* (*Miccotrogus*) *picirostris* Fab. In the letter accompanying the determination he stated that these three Puyallup specimens appeared to be the first authentic examples of this species in North America and that the name *griseus* Schaeffer would probably have to be used for the eastern species which for a number of years has passed as *picirostris* Fab. Blatchley and Leng,[1] in their discussion of *T. picirostris* Fab., state that the American species is the *Miccotrogus picirostris* Fab. of Europe although the genus *Miccotrogus* has but six segments in the funicle while the species they discuss has seven, and consequently they retain it in the genius *Tychius*. They also add that it is the *T. griseus* of Schaeffer. This synonymy apparently must now be discarded and *griseus* restored as the true name of the species present in the eastern portion of North America. Detwiler[2] gives a good discussion of the eastern species and mentions the fact that several author's have placed *picirostris* in the genus *Miccotrogus* but that Schoenherr who established the genus did not, and Detwiler refers to Blatchley and Leng for this statement in spite of the fact that there is no such reference in their treatment of the species.

Since the first three were taken the species has been swept from clovers and grasses in western Washington many times and records of capture are at hand for every month except December; undoubtedly specimens could be easily picked up in this month also if a search was made. Those collected during the winter months were taken mainly by sifting moss. One lot was obtained from debris left by receding flood waters of the Puyallup River, on January 9, 1932. On May 10, 1932, a patch of white clover was swept and an estimated thousand collected in a short time. Judging from their abundance on the various clovers it appears that here they prefer white, alsike, and red clovers in the order named. On September 9, 1933, a pair was taken a few miles southeast of Spanaway on the dry gravelly prairies and, so far as the writer could ascertain, some distance from any of the cultivated strains of clovers. However, a small yellow-blossomed clover, likely *T. dubium*, and *Cytisus* were rather abundant close by. Attempts to collect adults by sweeping the blossoms and seed pods of *Cytisus* and sifting debris from under the bushes have never yielded any weevils. Adults were swept from *Rubus parviflorus* and *R. spectabilis*, *Spiraea douglasi*, a plantain, and a species of sedge. Individual adults were observed feeding in the blossoms of a native strawberry and on the drupelets of ripe fruit of the Evergreen blackberry. The damage to strawberry would likely be negligible in any case but as the drupelets of the blackberry were punctured rather deeply, it is quite conceivable that these weevils could cause more or less damage in fields close to heavily infested clovers; the feeding punctures would be likely places for the development of molds and other fungi. Some of these berries had three and four punctures and the weevils were quite scarce in that vicinity.

To date the species has been taken at Puyallup, Sumner, Graham, a few miles southeast of Spanaway, near Falls City, and at Monroe. No attempt has been made to collect life-history data but several specimens were collected on August 8 and November 1. Whether one long-drawn-out generation or two or three generations are produced was not determined.

WM. W. BAKER, *Junior Entomologist, U. S. Department of Agriculture, Bureau of Entomology Laboratory, Puyallup, Wash.*

[1]Rhynchophora or weevils of northeastern America, 1916, p. 246.

[2]Three little-known clover insects, Cornell Agr. Expt. Sta. Bull. 420, 1923 pp. 20–27.

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A. A. A. S. Winter meetings, 1934-1935, Pittsburg; December 1935, St. Louis; Summer meetings, 1934. Berkeley, June 18-23; 1935. Minneapolis.

A Committee on Programs, with Dr. J. G. Sanders as Chairman, is attempting to work out a more acceptable presentation of papers than has heretofore obtained. The idea expressed at the last annual meeting was to the effect that a rigid limitation to five minute papers was interfering greatly with the value and interest of the sessions, and this is undoubtedly true. It has been overcome in part by symposia on some of the more important problems. These sessions have naturally occupied a prominent place in the series of meetings. At the same time, they have limited, by virtue of the time occupied, the number of papers which could be presented before the general association or its sections. It is impossible for an individual or group of individuals to work out a plan which will be satisfactory to all. It must necessarily be a compromise. All recognize the value of a certain amount of discussion. All desire an opportunity to present papers. All realize that some papers are more important than others, and it naturally follows, in view of these conditions, that all, for their own good and the good of their associates, must coooperate in supporting any reasonable modifications. The work of the economic entomologist is more or less seasonal. It varies from year to year, and if possible the make-up of the program should take this into account as well as a general policy which should apply to all annual gatherings. Those presenting papers can help solve the problem if they consider the problem as a whole and do what is possible to make their own contributions harmonize with

a general plan. There is no doubt of the desirability of more coordination of programs. It is not the number but the quality of the papers which counts.

Reviews

Entomology with Special Reference to its Ecological Aspects by JUSTUS WATSON FOLSOM, revised by R. A. WARDLE, Fourth Revised Edition, pages i–ix, 1–605, 5 plates and 308 text figures, P. Blakiston's Son & Company, Philadelphia, 1934.

This new edition of a well known, authoritative work comes at a most opportune time and will prove most acceptable to all interested in general entomology with special reference to its ecological aspects. The work has been thoroughly revised and brought down to date. The general arrangement and method of treatment is that of the earlier editions. The great advances in certain fields of entomology have necessitated the practical re-writing of several chapters, especially those dealing with insects and diseases and insects and man. The thirty-two pages of classified bibliography bring together an immense number of the more important citations relating to the various subjects discussed in the text.

The revision has been thorough and sympathetic, and those desirous of a volume dealing with the broader phases of ecological entomology will find their needs very satisfactorily met by this recent addition to scientific literature.

E. P. FELT

A Manual of Entomological Equipment and Methods, Part I, by ALVAH PETERSON, 21 pages, 138 plates, 12 tables, Edwards Brothers, Ann Arbor, Mich., 1934.

The author has brought within the confines of a lithoprinted work an account of much of the equipment or tools of the entomologist used in research work upon living insects. There is a brief discussion of field insectaries, illustrations with explanations of numerous insect cages and containers, a similar treatment of collecting, killing, sampling and sorting equipment, of insect traps and of the more technical apparatus, such as weather recording instruments, thermocouples, thermostats, and also of devices for humidity control, evaporation measurement, cabinets for controlled conditions and similar equipment. There are, in addition, tabulations of conversion temperatures, relative humidities, dew-point temperatures, pressures of aqueous vapors and conversions for metric and U. S. customary measures and weights. There is an excellent index.

This work is a revelation of the number and variety of devices used in entomological investigations and is most suggestive to all students of biology and collectors of insects. Constant reference to this work would greatly increase research efficiency and aid materially in standardizing methods. It should be available to all research workers. The numerous amateur entomologists throughout the country will find this publication exceedingly serviceable, though it is far more than a manual on the collecting, rearing and preservation of insects.

E. P. FELT

Current Notes

Mr. Raymond Bushland, M. S. June 1934 at South Dakota State College, recently selected as research assistant in the alfalfa insect work at Kansas State College, took up his duties July 23.

The Board of Governors of McGill University have appointed Dr. W. H. Brittain, formerly Professor of Entomology, Dean of the Faculty of Agriculture, Macdonald College. Dr. Brittain will retain his professorship for the present.

The Eastern Branch of the American Association of Economic Entomologists will meet November 22 and 23 at Hotel McAlpine, Broadway at 34th Streee, New York City. Attention is called to the Secretary's request in relation to one or more sessions of a round table nature.

Dr. E. Avery Richmond, who has been serving the past season as an expert on cranbery pests for the Plymouth (Mass.) County Extension Service, has accepted an appointment in the Pennsylvania Extension Service with headquarters at State College.

Dr. J. M. Swaine, the well-known Associate Dominion Entomologist of Canada, was appointed Director of Research for the Department of Agriculture, by Order-in-Council, in July. He will be attached to the administrative staff of the Department, and in his new position will work towards co-ordinating research work within the Department and with other organizations.

Dr. F. A. Fenton formerly Entomologist, Bureau of Entomology, U. S. Department of Agriculture working upon cotton insects and stationed at Presidio, Texas, has resigned his position to become State Entomologist of Oklahoma and Professor of Entomology at Oklahoma A. & M. College, Stillwater, Oklahoma. He has been appointed to the position recently made vacant by the retirement of Professor Sanborn.

Dr. Ralph L. Miller formerly Associate Entomologist, Bureau of Entomology, U. S. Department of Agriculture, stationed at Orlando, Florida, resigned his position July 15 to become Entomologist with the Freeport Sulphur Company and is now stationed at New Orleans, La. He will be interested in the promotion of sulphur in agriculture but will pay special attention to the use of sulphur in insecticides.

The continued seriousness of the chinch bug in the central west prompted the calling of a second conference at Hamilton, Illinois, Sept. 5, 1934. The first conference was held at the same place in September, 1933. A complete and profitable discussion of the problem resulted. Thirty six persons attended the conference, including representatives from the federal Department of Agriculture and the following states: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, and Oklahoma. W. P. Flint acted as chairman and J. J. Davis as secretary of the conferences.

The annual meeting of the International Great Plains Conference of Entomologists met at Itasca Park, Minnesota, August 8 and 9. Representatives were present from many of the prairies states and the Prairie Provinces. The Entomological Branch of the Canadian Department of Agriculture was well represented. Messrs. H. L. Seamans, K. M. King, R. D. Bird, A. P. Arnason, R. Glen, R. H. Painter, R. M. White, R. H. Handford, C. W. Farstad and L. C. Paul represented the Division of Field Crop

and Garden Insects; K. E. Stewart represented the Division of Forest Insects, and P. C. Brown the Division of Foreign Pest Suppression. The conference dealt largely with the subject of grasshoppers and their control, and as all Branch officers present had been engaged upon this work during the summer, the meeting was a most profitable and stimulating one. The prospects in Western Canada are for a continued outbreak of grasshoppers in 1935.

A United States Entomological Laboratory of the Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine was established at Manhattan, Kansas, during July, 1934. The laboratory, which is under the immediate direction of Dr. R. T. Cotton, will be engaged in stored grain and flour mill insect investigations throughout the United States, and in cereal and forage insect investigations in several of the west central states. The personnel of the station at the present time consists of the following: Dr. R. T. Cotton, Mr. Newell E. Good, Mr. H. D. Young (of the Insecticide Division, Bureau of Chemistry and Soils) all of Washington, D. C.; Mr. George B. Wagner and Mr. T. F. Winburn, both of whom were transferred to the new laboratory from the discontinued Kansas City Stored Grain Insects Laboratory.

Horticultural Inspection Notes

Six persons have been arrested and fined in Arkansas since January 1, 1934, for transporting nursery stock or other plants into that State without a permit, according to the Arkansas State Plant Board News for August 1.

California circular No. 6, relating to the grape Phylloxera, was reissued as quarantine proclamation No. 17, on July 6, 1934, in order to bring it under the provisions of the present agricultural code. No material change was made in the restrictions.

Luis F. Correa, Inspector of the Plant Quarantine Service of Porto Rico, has been transferred from the port of San Juan to the port of Arecibo, and Inspector Emilio E. Gautier has been transferred from the latter port to San Juan. These changes were effective August 1.

The Wisconsin quarantine relating to the alfalfa weevil was revised effective August 15 to extend the territory in California, Nebraska, Nevada, and Oregon, and to prohibit the entry of alfalfa meal during the winter months, the remainder of the year remaining open for entry of certified meal.

The Pennsylvania quarantine relating to the gypsy moth was extended, effective September 1, to include three additional townships, and part of a fourth, in the counties of Carbon, Lackawanna, and Monroe. Movement of products within the regulated areas was also placed under regulation in order to prevent reinfestation in eradicated sections.

Josephine County, Oregon, has recently been infested with the alfalfa weevil, and the States of Oregon, Wisconsin, and California extended their quarantines accordingly. The latter also extended the termination date of the period during which hay may be moved into the interior infested area of California, from March 31 to April 30, and approved hay movement from southern Oregon over a designated railroad.

To bring about a closer coordination of research along related lines in the Department of Agriculture, Secretary Wallace has issued an order under which the divisions of Soil Fertility and of Soil Microbiology were transferred from the Bureau of Chemistry and Soils to the Bureau of Plant Industry on September 1, and the Insecticide Division of the Bureau of Chemistry and Soils to the Bureau of Entomology and Plant Quarantine, on the same date.

Under an amendment to the Federal pink bollworm quarantine regulations, effective September 19, the counties of Jackson and Suwannee in the State of Florida were brought under restriction. This change is due to the finding of a light but scattered infestation in those counties during the past few weeks. No other changes are made in the regulated areas at this time.

Effective September 16, the restrictions on the movement of fruits and vegetables under the Japanese beetle quarantine regulations were removed for the season. The restrictions on cut flowers, however, remain until October 15. Under the quarantine regulations, certificates showing freedom from Japanese beetle are required on shipments of certain kinds of fruit sand vegetables until October 15. The effect of the order is to release the fruits and vegetables from that requirement a month earlier than is provided in the regulations themselves.

Willow withes used as ties or otherwise in connection with shipments of plant materials for propagation, from Europe, including the British Isles and Ireland, will be refused entry into the United States, effective October 1, 1934, under a notice (BEPQ-365) issued by Lee A. Strong, Chief of the Bureau of Entomology and Plant Quarantine, under the provisions of Quarantine 37. The reason given for the embargo is that willow withes taken from plants infected with the destructive watermark disease may readily disseminate that malady, since the bacterial organisms concerned (*Bacterium salicis* Day and *Pseudomonas saliciperda* Lindeijer) may be carried with the tissues.

Dr. Karl F. Kellerman, in charge of the division of plant disease control, Bureau of Entomology and Plant Quarantine, died on August 30, in Garfield Memorial Hospital, Washington, D. C., after a brief illness. Secretary of Agriculture Wallace says that with his death the world has lost an internationally known scientist whose contributions to agriculture have been a credit to the Department and whose loss will be keenly felt by friends and co-workers the country over. Since 1933, Dr. Kellerman has had charge of all of the regulatory work associated with plant diseases in the Bureau, including the white pine blister rust work, black stem rust and barberry eradication, eradication of the Dutch elm disease, citrus canker, and the phony peach disease.

The Arkansas State Plant Board, on July 26, suspended all its interstate quarantines on nursery stock. These related to chestnut blight, black walnut canker, and European red mite, the latter quarantine restricting the entry of most of the fruit trees and several ornamentals from a large number of States. The Board announces it will herafter "attempt to exclude these and other pests from Arkansas by means of a more stringent application of the permit system [and] will no longer issue permits to ship nursery stock into Arkansas on the basis of the usual blanket certificate of inspection, but will call upon the nursery inspector of the State in which the nursery is located for information which will show the true condition of the applicant nursery as to the various pests in question. * * * Assurance will also be required from the nursery inspector * * * that stock objectionable to the Board which the applicant nursery mighy buy from another nursery will not be shipped into Arkansas."

The Dominion of Canada recently placed a regulation relating to the phony peach disease under which shipments of the host plants from any part of the United States are required to be certified as originating in a disease-free nursery, and a disease-free environs within one mile of the nursery, and certified as free from the peach borer. Other recent regulatory actions of the Dominion which affect the United States include modifying the requirement as to routing stock shipments via Vancouver when destined to British Columbia; rescinding the embargo on gladiolus shipments to British Columbia, which had been placed on account of gladiolus thrips; extending the European corn borer quarantine to apply to Kentucky, Maryland, and Virginia, among other States; prohibiting the importation of tobacco seed on account of the blue mold disease, and of elm logs or burls on account of the Dutch elm disease; and requiring a permit for the importation of any living insect or fungus except the honey bee. These various changes were adopted in May and June 1934.

Several members of the State Plant Board of Mississippi are taking graduate work at some of the leading departments of entomology in the country. D. W. Grimes, Inspector with headquarters at Durant, Miss., returned to duty in September after spending the summer at Ohio State University. Ross E. Hutchins, Assistant Entomologist at State College, has been granted leave of absence to attend Iowa State College during the present session. Clay Lyle, Entomologist and Executive Officer, State College, spent the summer at Iowa State College and will be at the same institution for the fall quarter. A. L. Hammer of the Mississippi Experiment Station will be at Ohio State University during the present session. M. R. Smith, in charge of Argentine ant investigations for the United States Bureau of Entomology for the past three years, is now employed cooperatively by the Mississippi State Plant Board, Mississippi State College and Experiment Station. He will conduct investigations on the control of the fire ant and assist with the prosecution of Argentine ant campaigns.

The Green Fruit or Peach Beetle, *Cotinis texana* Casey, in California. According to the literature to date no record of the green fruit or peach beetle, *Cotinis texana* Casey, has been made in California. In September 1934 the writer collected this insect feeding on figs and grapes in the city of Riverside. It has a distinct liking for ripe peaches, and also freely eats apricots, apples, muskmelons, nectarines, pears, tomatoes, and the fruit of cacti. *Cotinis texana* Casey measures from 20–34 mm. in length, robust, widest at the bases of the elytra, margin of brown on elytra, flat on dorsum, dull green above, venter an iridescent green. Since the larvae are known to breed in dung it is possible that it was carried into this state in manure shipments from Arizona or New Mexico.

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